Wolfgang Schneider, DJ 8 ES

VHF, UHF and SHF Measuring Methods Using a PC

Part 1: Essentials of Control Using the PC's Centronics Port

Developing VHF, UHF and SHF measuring methods is an ambitious goal. Radio amateurs can simply not do without measuring methods now, in connection with building their own equipment or even operating their own radio systems. Obtaining the apparatus required for this is not always simple, and is certainly not always inexpensive.

1. INTRODUCTION

There are particularly interesting possibilities for DIY work in the area of measuring methods. Numerous different publications in the relevant amateur radio literature support this opinion. Whether it's a test transmitter, a milliwatt metre or even a spectrum analyser - as Robert Lentz, DL3WR, once wrote in VHF Communications - "state of the art technology comes to DIY assembly".

All these devices have one thing in common, they should be usable over as wide a range as possible. But it is not sufficient for the milliwatt metre to function well at 23cm alone. It must give readings which are just as precise in the short-wave range, at 2m or 70cm.

And it's precisely here, when we come to deal with wide-band linear operation, that the problems really begin. The computer can help us here to a really miraculous extent. Linearisation of tuning characteristics in the test transmitter, automatic calibration of the wattmeter, zero offset compensation, etc.. The list of possibilities is virtually endless.

Specifically, this series of articles will deal with the themes of input and output units for Centronics interfaces, mW meters, frequency synthesisers, and a computer-controlled measuring position, with additional options for a wobbler and a spectrum analyser.

2. POSSIBLE LINKS TO A PC

However, before this universal measuring position comes into being, the principles must be set out first. This applies, in particular, to the digital world of the personal computer. Computers can now be found in the shacks of the majority of radio amateurs. To start with, we used the C64 or ZX81 for applications which were still "relatively limited".

Now you can find virtually everything in the PC line which is available on the market.

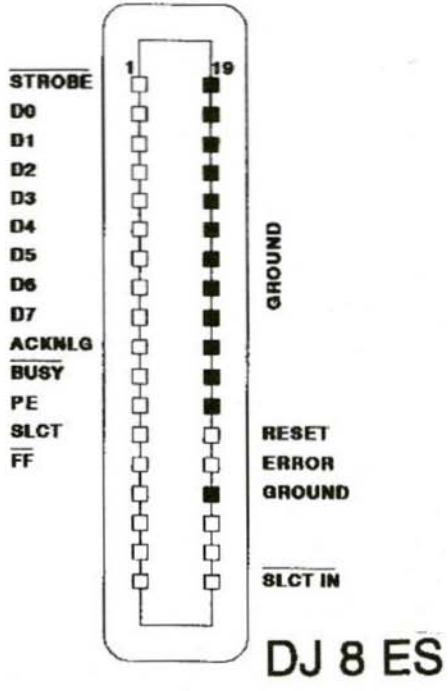

Fig.1: Pin-Assignment for a 36-pin-Centronic Connector

If the computer is to take over control functions, it must be able to communicate with the outside world. That's what interfaces are for.

2.1. Parallel Interfaces

Any commercially available PC has at least one parallel interface as per the Centronics norm as a standard feature, to which the printer is connected - but this interface can do much more!

The data traffic between the PC and the printer is carried on through a minimum of 8 data circuits and 4 control circuits.

When data are transmitted, the transmitter sends the data item on circuits D0 to D7 and checks whether the subscriber is ready to receive data (BUSY).

As soon as the BUSY circuit accepts a logic 0, the transmitter generates a STROBE signal (briefly, a logic 1) and enters the information into the peripheral.

The printer acknowledges using the ACKNLG signal (ACKNOWLEDGE).

The PE circuit (PAPER EMPTY) signals that the printer has run out of paper.

These four control circuits are all that is needed for data transmission.

Many printers have additional control options. I shall not be going into these additional options in greater detail here and now. But they are included in Fig.1, for the sake of completeness.

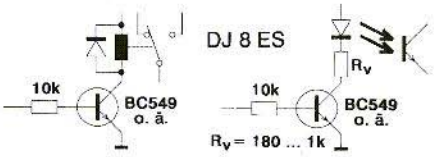

Fig.2: Driver Circuit for Driving Switching Stages

2.2. Control using the Centronics Interface

The circuits referred to above can be used as follows in control technology:

D0 to D7 as exit

STROBE as handover signal

ACKNLG, BUSY, PE as entry

All circuits on the Centronics interface operate at transistor transistor logic level. Switching stages, transducers, etc. can be connected up directly here. Due to the fact that the switchable power is only "low", drivers (e.g. 74LS244 or LS245) should be looped in. They provide multiple amplification for the switching current.

To wire up lamps, motors, etc., relays must sometimes be inserted into the circuits. Optoelectronic couplers are used here too, for de-coupling, and so are electronic load relays.

De-coupling an be recommended, especially for applications using supply voltage (or at higher voltages). Fig.2 shows simple driver circuits for driving switching stages.

2.3. Adapter Cards for Experiments

A simple and easily monitorable adapter card is useful for the first practical tests.

The circuit is shown in Fig.3. It includes the bus driver for the output circuits D0 to D7 and, as an updated status display for all circuits, LED's of various colours.

With this adapter card, we can "see" what's going on in front of us (Fig.4). Fig.5 shows the components plan for the double-sided printed circuit board.

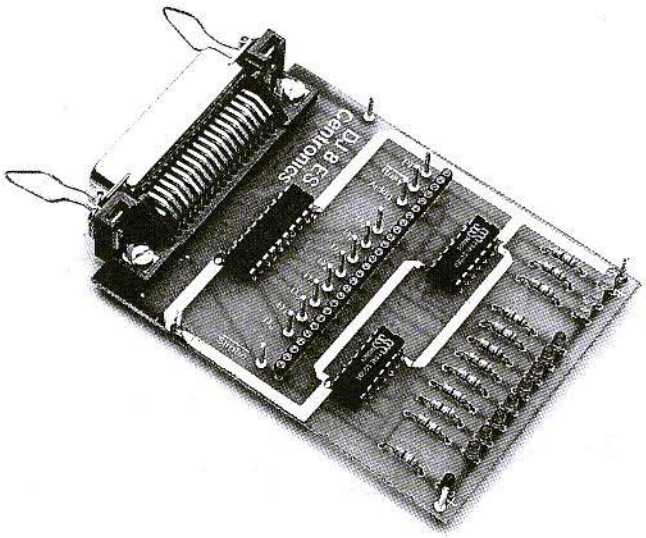

Fig.3: The Centronics Adapter Card Fully Assembled

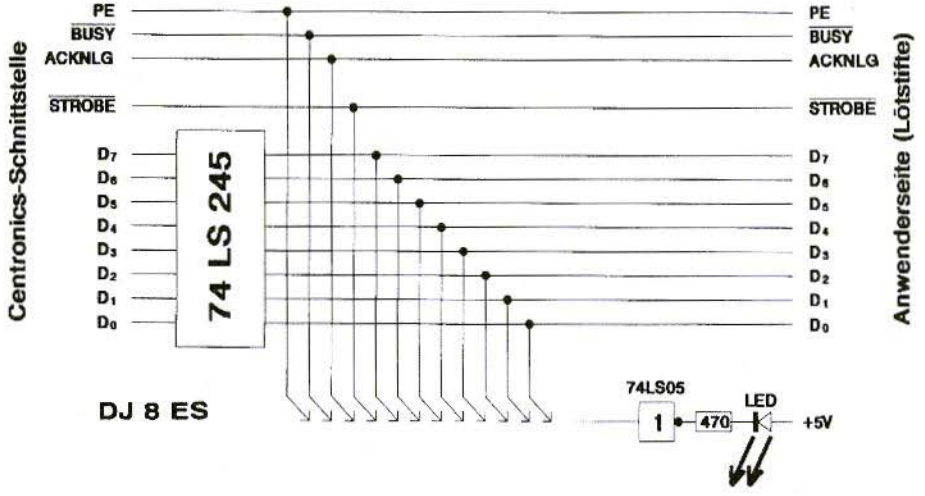

Fig.4: Centronics Adapter Card Circuit: *Schnittstelle* = Interface

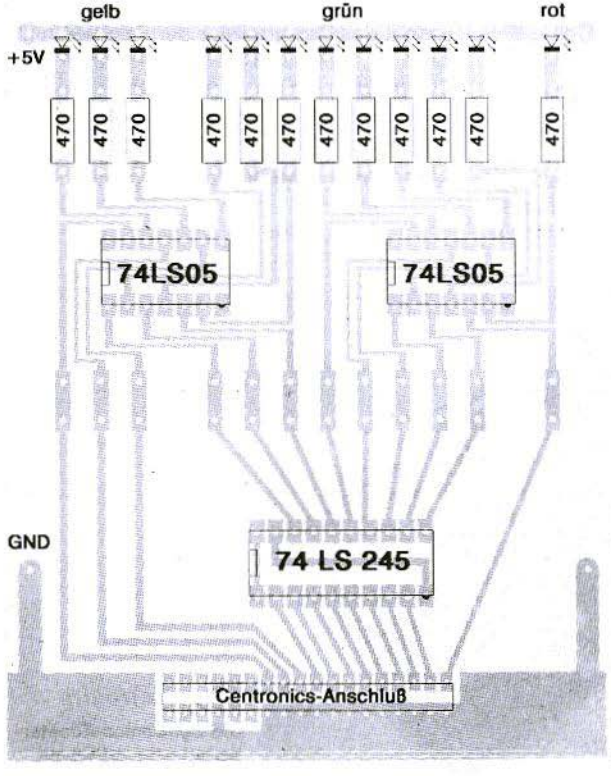

Fig.5:
Components Plan of Adapter Card

Gelb = Yellow;
Grün = Green;
Rot = Red;
Anschluß = Connection

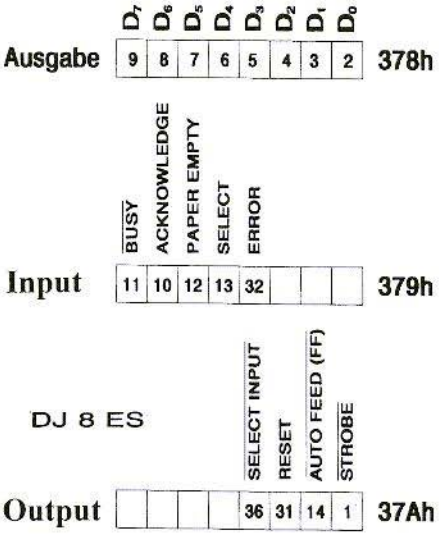

Fig.6: Allocation of Control Signals to corresponding Register

3. ACTUATING THE INTERFACE

The PC must be appropriately programmed so that it can communicate with the outside world.

The logic address(es) of the built-in Centronics interface in the computer is/are important in this context. This is/these are dependent on the hardware configuration:

278h - 27ah

378h - 37Ah or

3BCh - 3BEh

In each case, the first address - 278h, 378h or 3BCh ("h" signifies "option" in hexadecimal) - actuates the data register of the parallel interface. Data can be entered into this 8-bit register by the computer, to be output to the external equipment.

D0 - Pin-2

D1 - Pin-3

up to

D7 - Pin-9

The second address in each case - 279h, 379h or 3BDh - actuates the so-called status register of the interface. Special replies from the printer are deposited in this register, when ACKNOWLEDGE is

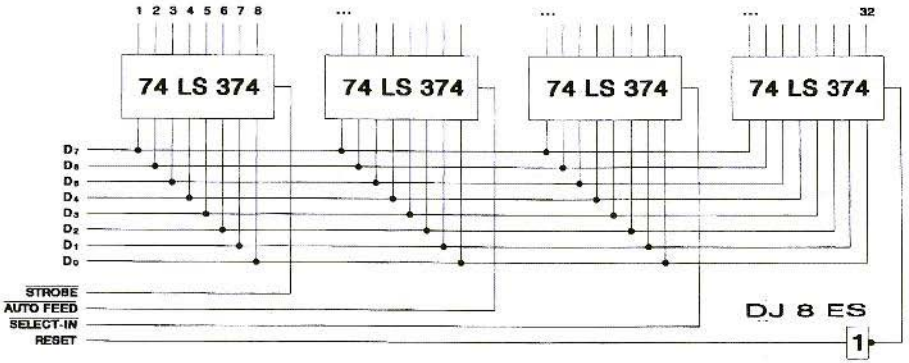

Fig.7: Register as Output for 4 Data Items, each 8 Bits long

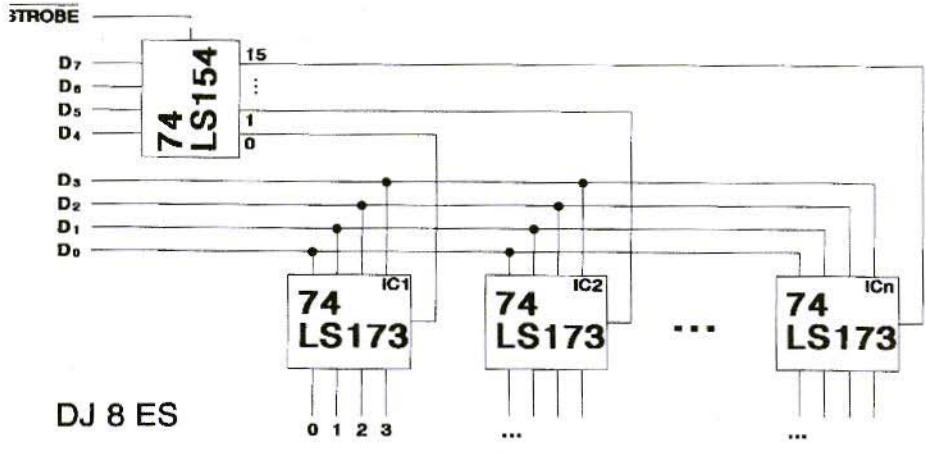

Fig.8: Output Unit organised as 16 x 4 Bits

there on bit 6 (pin-10), BUSY on bit 7 (pin-11) and PAPER END on bit 5 (pin-12). The third address in each case - 27Ah, 37Ah or 3BEh - actuates the control register of the interface. Here we find the STROBE signal on bit 0 (pin-1).

N.B.: The STROBE signal is output in inverted form. For example, if it is desired to output a "1" on the STROBE circuit, a "0" must be entered in bit 0! Various other circuits are also inverted! The signals are correspondingly identified.

Fig.6 shows the allocation of all control signals to the various registers. For example, here we have the contents for the addresses 378h, 379h and 37Ah. The boxes show the relevant pins of the 36-pin-Centronics connector.

3.1. Test Program in BASIC

A simple Basic program checks the functioning of the adapter card. As a first step, a running light is programmed for the output circuits, so that the STROBE flashes. The three input cir-

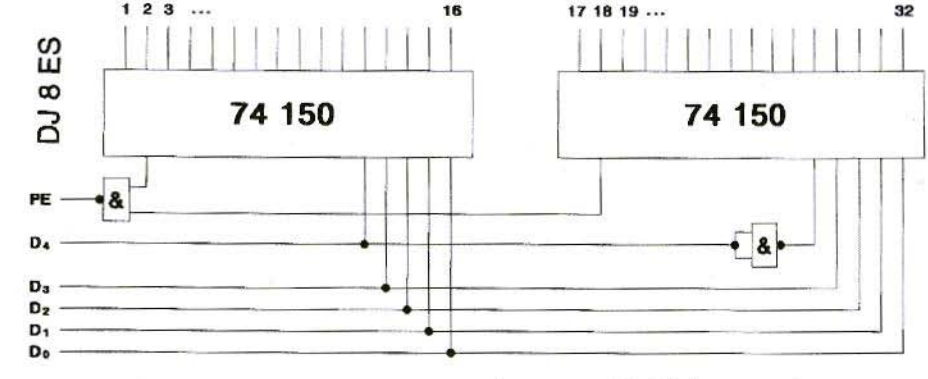

Fig.9: Circuit Proposal for 32-bit Input into Time Multiplex

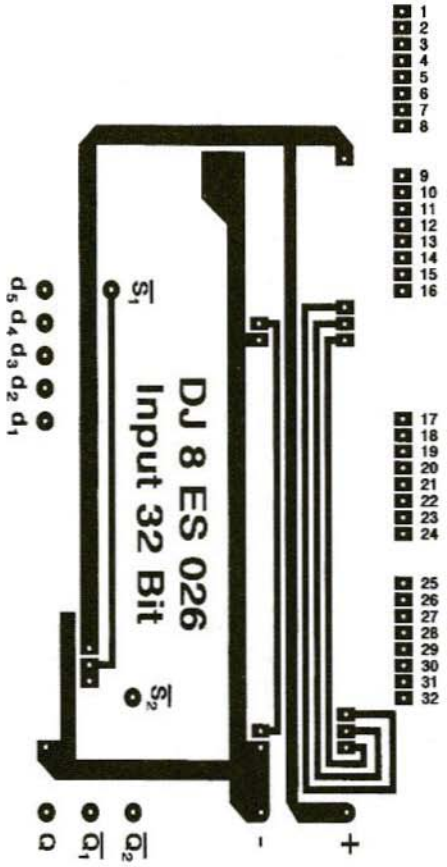

Fig.10: 32-bit Input Unit

cuits already named can then be tested. The updated status is always shown on the corresponding output bit. N.B.: BUSY is inverted!

```
100 REM function test
110 Set REM port "0"
120 REM adr 378h = 888d
130 OUT 888.0
140 OUT 890.1
150 REM running light
160 FOR I = 0 TO 7
170 I = 1.2
!80  OUT 888.1
190 FOR J = 0 TO 100
200 NEXT J
210 OUT 890.0
220 FOR J = 0 TO 100
230 NEXT J
240 OUT 890.1
250 NEXT I
260 OUT 888.0
270 REM input test
280 A = INP (889)
290 A = A AND 224
300 OUT 888.A
310 GOTO 270
320 END
```

3.2. Output functions

Merely observing flashing LED's is also not satisfactory in the long run.

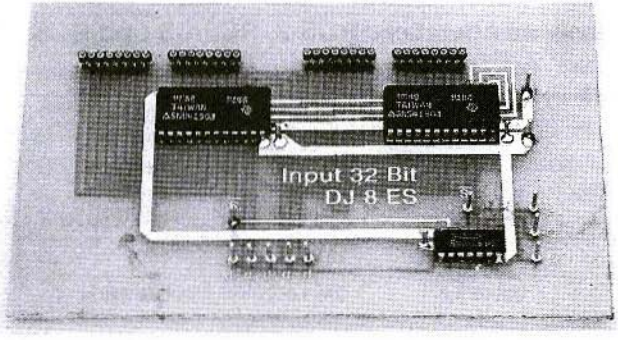

Fig.11: Experimental Setup for 32-bit Input Unit

It certainly looks nice, but my PC is supposed to be controlling something! For the PC to be able to take over this control function, it has to "talk" to the world beyond itself. This leads us directly to one of the most important aspects of the interface, namely the inputting and outputting of data.

The simplest case (8-bit output) can be covered by the Centronics interface immediately and without any expansion of any kind. If applicable, STROBE can be used, in addition to the 8 bits D0 to D7, as an interchange signal for peripherals.

```
100 REM output
110 REM data
120 OUT 888, DATA
130 REM STROBE signal
140 OUT 890,0
150 OUT 890.1
```

A further interesting output option can be implemented in an easily monitorable way using 4 x 8 bits. In addition to STROBE, the circuit shown in Fig.7 also uses the other output signals RESET, SELECT-INPUT and AUTO-FEED (FF) as interchanges, with the data being entered in output latches in 8-bit blocks.

3.3. Data output in time multiplex

It is also possible to output data by means of the time multiplex process. This method considerably increases the number of ports which can be differentiated. Here Fig.8 shows a path for a maximum of 16 x 4 bits. The individual data items for each 4 bits are transmitted sequentially in this system.

```
100 REM output time multiplex
110 REM  data + address
120 FOR ADDRESS = 0 TO 15
130 OUT 888, DATA + ADDRESS*16
140 REM STROBE signal
150 OUT 890.0
160 OUT 890.1
170 NEXT ADDRESS
```

3.4. Input function

At first glance, it looks as if even more effort is required for input. And yet there are only 5 input bits there in all. As a rule, this is too few. Only a time multiplex process can be considered for inputting entire data items (1 byte or more).

Fig.9 proposes a circuit for inputting 32 bits. The individual bits are sequentially scanned and read in through the PAPER EMPTY (PE) circuit. For this purpose, the data circuits D0 to D4 select the individual input channels. The desired data formats (e.g. 4 x 8 bits) are then set up internally through software.

```
100 REM input time multiplex
110 FOR ADDRESS = 0 TO 31
120 OUT 888, ADDRESS
130 INPUT = INP (889) AND 32
140 INPUT = INPUT/32
150 PRINT ADDRESS, INPUT
160 NEXT ADDRESS
```

Fig.10 shows one side of the printed circuit board for the 32-bit input unit, which is coated on both sides. The prototype for this experimental printed circuit board can be seen in Fig.11.

And now all the best for your first experiments.

To be continued

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VHF, UHF and SHF Measuring Methods Using a PC

Part-2: Milliwatt Meter From Short Wave To SHF

A wattmeter is definitely a necessity for the active radio amateur, and there's probably one in every shack. But what about low-power measurements?

Is the VFO still supplying the correct output level, or what's the control power level for the transverter? Or, or, or... A simple mW meter can help in many such cases.

1. GENERAL

Many descriptions have been written in the relevant amateur radio literature in the past on the assembly of milliwatt meters - and I hope this will continue in the future. Two main measuring methods could be distinguished:

1. Thermal power measurement (bolometer), and
2. Measurement using high-frequency rectifier diodes

This article will neither be dealing with the theoretical principles of the two options nor contrasting their advantages and disadvantages.

Whether a bolometer or a diode detector is used, they have one problem in common - the linearity over a frequency range as large as possible. It is just not good enough if the milliwatt meter merely works well at 23cm - it must give readings just as accurate for shortwave, from 2m to 70cm.

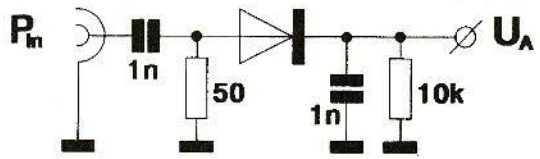
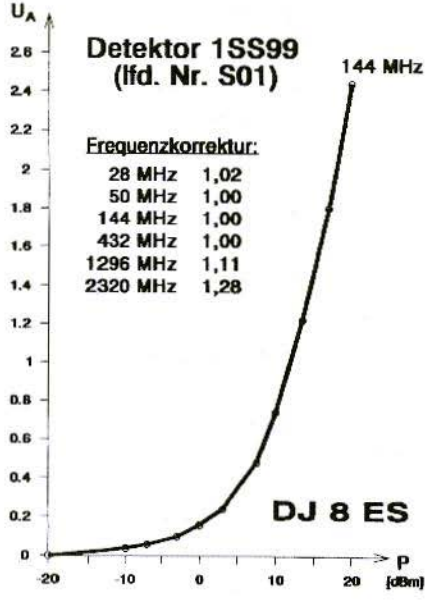


Fig. 1: Diode Detector with High-Frequency Rectifier Diode



dBm	mW	U_A
+20	100,000	2,450
+17	50,000	1,748
+14	25,000	1,195
+10	10,000	0,738
+ 7	5,000	0,476
+ 4	2,500	0,315
0	1,000	0,153
− 3	0,500	0,085
− 6	0,250	0,047
−10	0,100	0,020
−13	0,050	0,012
−16	0,025	0,008
−20	0,010	0,003

Fig. 2:
Output Voltage, dependent on Power and Frequency
Detektor **= Detector;** ***Lfd. Nr.*** **= Ser. no.;** ***Frequenzkorrektur*** **= Frequency correction factor**

Many authors offer interesting analogue solutions to this problem in their publications. But there are others too!

Linearisation of characteristics, automatic calibration of the power meter, zero point correction, etc. - you can confidently entrust these jobs to the computer!

What is described below, then, is an mW meter which enjoys the advantages of a PC. A simpler and faster way to measure power is the aforementioned method using high-frequency rectifier diodes. Fig.1 shows the standard circuit.

The output voltage, U_A, which is dependent on the input power, P_{IN}, and the frequency response are important values for the description of the circuit. The characteristics can be plotted simply, using adjustable output power and a voltmeter as accurate as possible, e.g. a digital gauging instrument.

The ratios are shown in graph form in Fig.2 and are listed systematically in the table.

Another simple circuit (Fig.3) operates with simultaneous voltage doubling. Two germanium diodes (type AA119) supply an output voltage proportional to the input voltage.

2. THE CIRCUITS

2.1. The Detector

A measurement detector should fulfil various criteria:

The wide dynamic range is provided by a type 1SS99 Schottky diode. Moreover, the wide frequency range goes from the

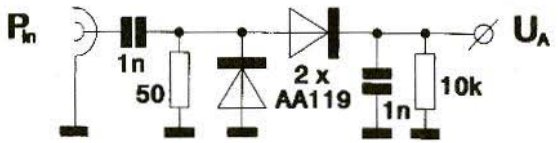


Fig. 3:
High-Frequency Rectification with Voltage Doubler

short wave right into the GHz range. Apart from the components selected, the main factor determining the frequency is an assembly appropriate for high frequency! Fig.4 shows the circuit of the measurement detector for frequencies of up to 2.5 GHz.

2.2. The A / D converter for the mW meter

The detector supplies an output voltage proportional to the input voltage (Fig.2). The high-Ohm input de-couples the measurement detector from the rest of the circuit. This is brought about via an operational amplifier (¼ LM324) with V = 1. The subsequent comparator compares the reading with a comparison voltage generated by the PC. In accordance with the up-to-date condition, there is 0 V or + 5 V at the PE connection ("paper empty").

The PC controls the entire measurement procedure through the Centronics interface.

The comparison voltage just referred to is generated by a D / A converter (ZN426E-8) from an 8-bit data word. The validity range runs from 0 to 255_{dez}.

The procedure uses the successive approximation principle.

Rapid D / A conversion is accomplished with the help of this method. An attempt is made to guess the voltage reading. Naturally, this sequential process is not carried out randomly, but is done in accordance with a balancing process, in accordance with which one feels one's way towards the desired value in a few steps. Naturally, this happens very fast if a PC is used.

When the measurement begins, the value is fed into the D / A converter which corresponds to exactly half the maximum voltage. A comparator reports whether the comparison voltage is higher or lower.

If the voltage to be measured lies in the bottom half of the range, this is divided again into two halves. If the upper segment is involved, the procedure is exactly the same.

Thus each new experiment narrows the voltage range down more and more. For 8-bit accuracy, the successive approxi-

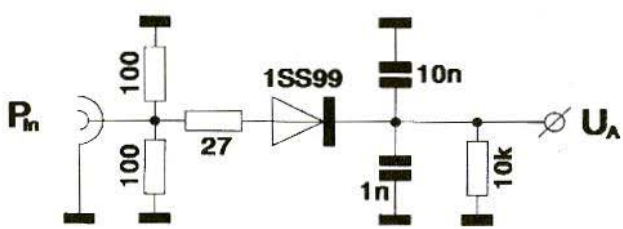


Fig. 4:
The completed Circuit with an 1SS99 as Detector

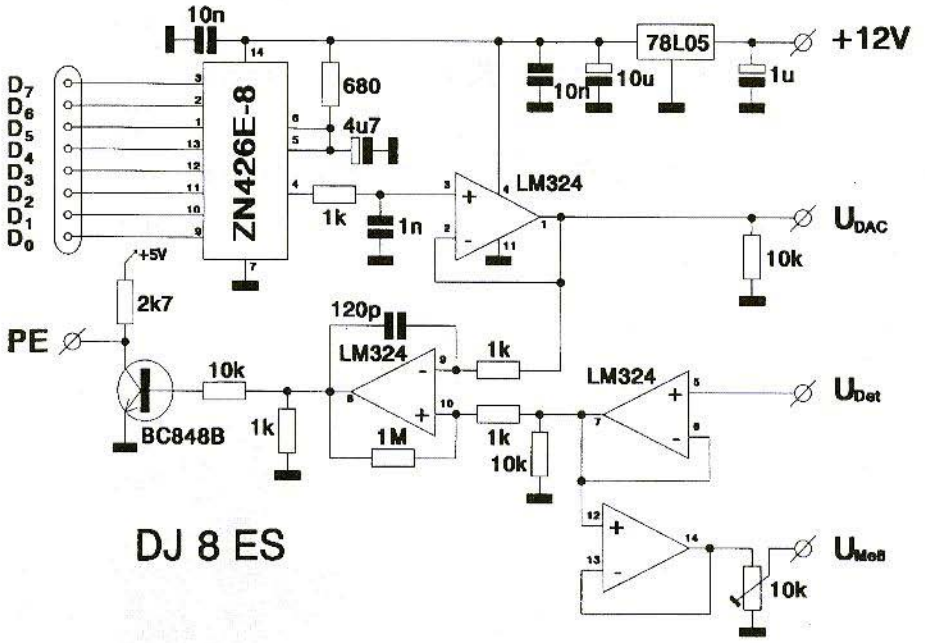


Fig. 5: The complete A / D Converter with Centronics Interface

mation procedure requires only eight steps to yield a result.

The comparison voltage (U_{DAC}) of the A / D converter is fed out as a check. Anyone who wants to may connect a simple direct reading instrument to point $U_{Meß}$ to obtain a relative display.

3. SOFTWARE

The flow chart on the following page-(Fig.7) shows the steps of the process very clearly.

The screen is set up as a first step. This must be done before the actual measurement routine begins.

The prevailing reading is continuously transmitted in an endless loop, and converted into the proportional power with the help of the detector characteristic line from Fig.2.

Last of all, it only remains for a correction factor to be brought into action, corresponding to the measured frequency. The frequency range can be adjusted for this purpose at any time via input through the keyboard.

The measured power is displayed on the screen in mW and dBm. The readings can be displayed as a graph without further ado. There are no limits to what the interested programmer can do here.

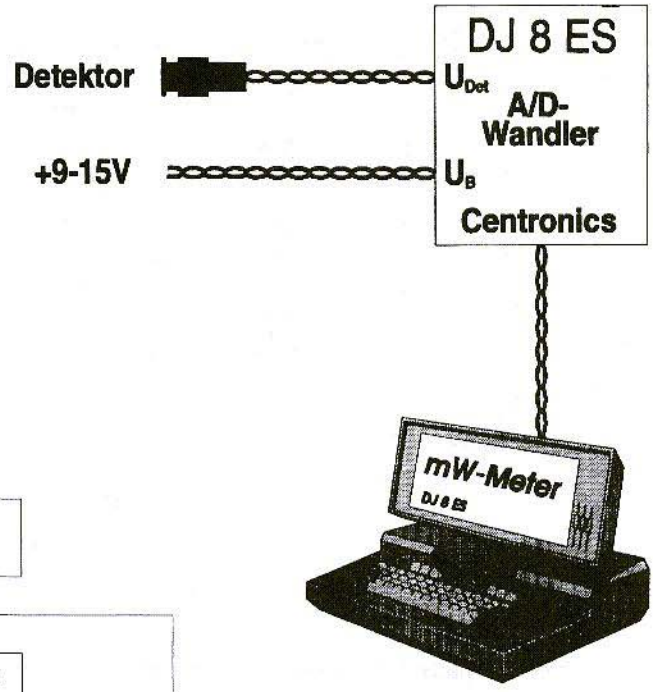


Fig. 6: Hooking up the Detector, the A / D Converter and the PC
Detektor **= Detector;**
A / D Wandler **= A / D converter**

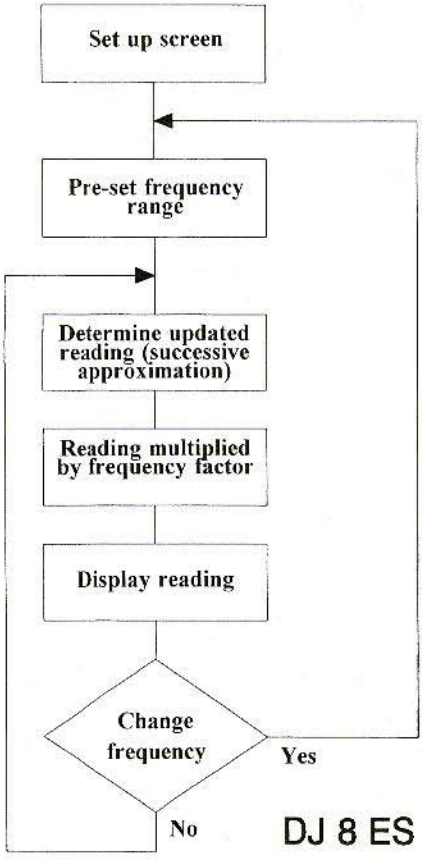


Fig. 7: Flow chart

4. ASSEMBLY INSTRUCTIONS

Special attention should be paid when assembling the measurement detector. A suitable assembly for high frequency is an absolute must for the desired broadness of band! That means short connecting wires, tidy earth connections and a mechanically stable structure.

The carrier material can be, for example, the hexagon nut from a BNC plug, sawn off in advance. Don't forget to de-burr it!

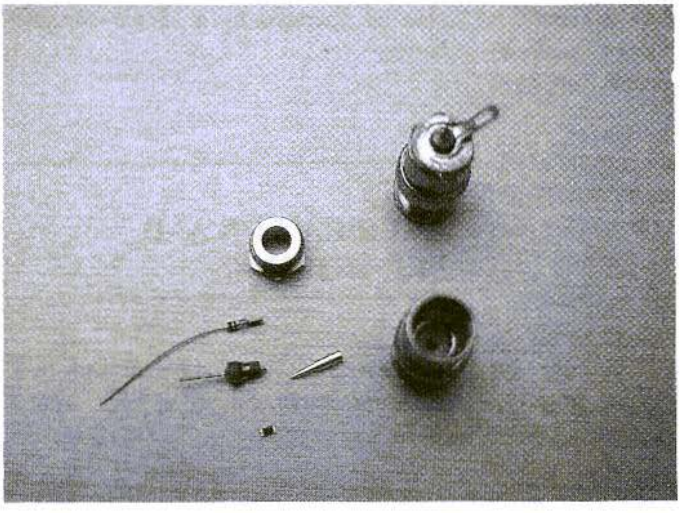


Fig. 8:
Individual Detector Components

The small number of structural components is soldered onto or into the residual threaded section and then provided with short wire ends (CuAg, diameter 1mm) for plug and socket. The detector prepared in this way is now screwed into the plug and coupling housing. When functionality has been successfully tested, a drop of rapid-acting adhesive fixes all components of the completed measurement detector.

Fig.8 shows additional details regarding the layout and incorporation of the components.

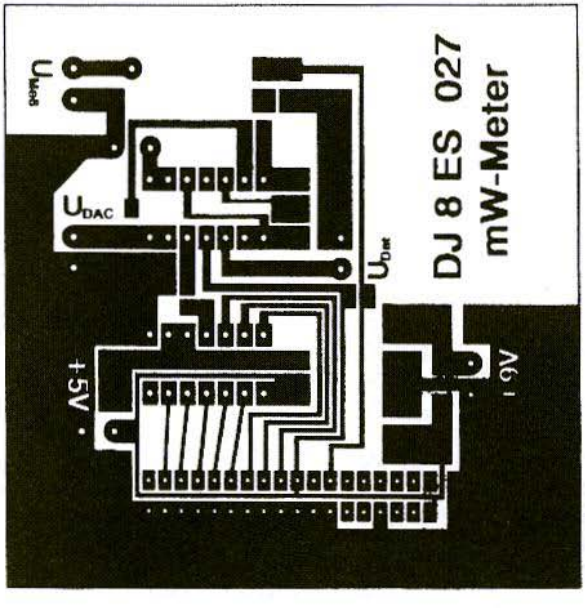


Fig. 9a:
mW Meter Layout DJ8ES 027

The board for the A / D converter is double-sided coated epoxy material 1.57mm thick. The board measures 75mm x 75mm..

Matching bores are to be provided for the IC's and the trimming potentiometer. The same applies to the Centronics plug and the U_{DAC}, U_{Dat}, $U_{Meß}$ and + 12 V connections.

Right up to the Centronics plug, all the components are mounted on the foil side! This also applies to the IC's and the trimming potentiometer (Fig.9).

All earth connections are soldered on both sides. The earth surface may not be milled down in advance here!

Finally, the entire circuit can be incorporated into a housing, as selected. A high-quality plug connection should be taken into account for the measurement detector (Fig.10).

The low current consumption for the circuit - app. 12mA at 9V - means it can also be operated by a simple compact battery.

5. CALIBRATION AND PRE-SETTINGS

The complete calibration of the mW meter assembly can be divided into 4 steps:

– Characteristics of Diode Detector

For the diode detector, the output voltage should be measured in relation to the input power. An expedient way to do this is to use a digital voltmeter and a 144 MHz standard signal generator. A transceiver with an adjustable transmission power will also fit the bill, of course. Fig.2 shows the levels and some possible step sizes.

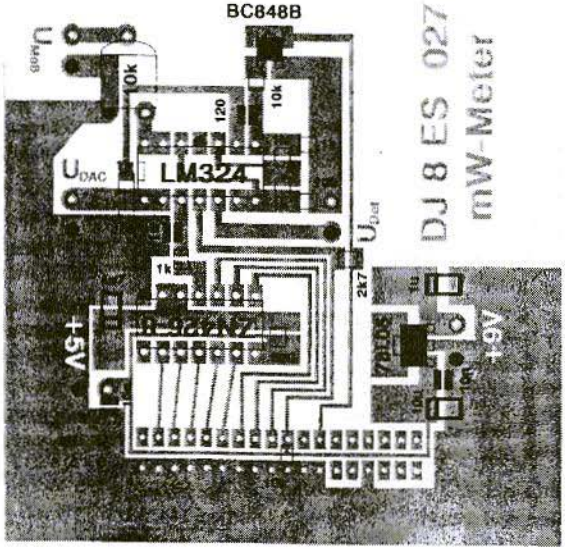


Fig. 9b: Component Plan of A / D Converter Assembly

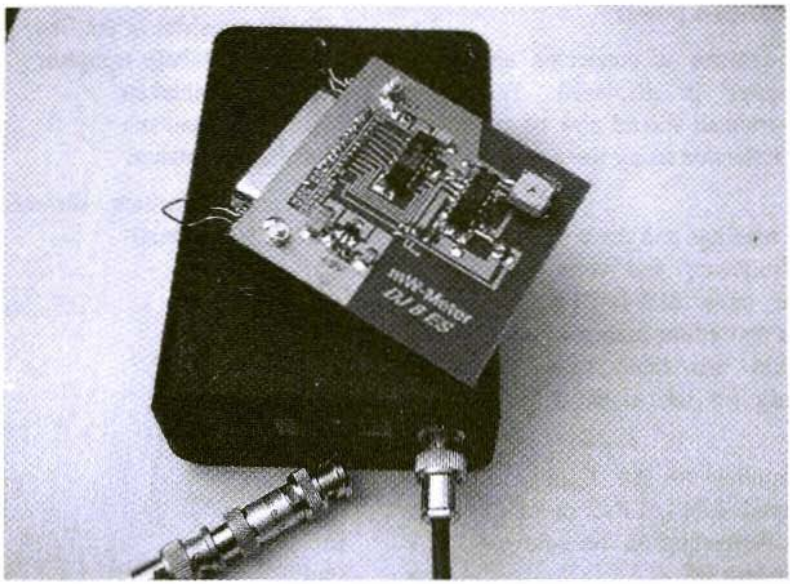


Fig. 10: The Printed Circuit Board alone and as Fully Completed Unit

An appropriate measurement graph is usually provided with ready-made measuring heads.

If we increase the number of measurement points, the accuracy of the equipment can be further increased. The program is designed for a minimum step width of 1dB. The corresponding values should be entered in a table.

– Correction factor δf

Particularly at high frequencies, the actual input impedance deviates from the expected value by 50Ω. A correction factor, δf, theoretically balances this out.

The factor should be measured for the frequency ranges 28, 50, 144, 432, 1,296 and 2,320 MHz, with a control power of, for example, 1mW (0dBm):

$$\delta f = \frac{\text{Rated value at 144 MHz}}{\text{Measured value}}$$

– Correction factor δU

Tight tolerances in the components, or even in the D / A converter ZN426E-8, lead to discrepancies in the measured voltage. The factor dU acts as a theoretical correction factor. It has a value of app. 0.01. The reference voltage, U_{Ref}, can be precisely measured at pin 5/6 of the D / A converter with a digital measuring instrument.

$$\delta U = \frac{U_{Ref}}{256}$$

– 10k Potentiometer for relative display of measured power

If no diode detector is connected up, maximum power is displayed. The measuring instrument should now be set to end-scale deflection using the potentiometer.

The detector readings and the correction factors for frequency and voltage are listed in the table MWTABLE.TXT. Any standard text editor makes it possible to correct this table using the updated values for the diode detector used.

This also applies to the Centronics interface desired. LPT1, LPT2 or LPT3 can be used, depending on the configuration of your own PC.

6. COMPONENT LIST

1 x	1SS99 Schottky diode
1 x	ZN426E-8 D / A converter
1 x	LM324 operations amplifier
2 x	UG88 A/U BNC plugs
1 x	UG89 A/U BNC cable jack
1 x	36-pin Centronics jack (printing installation)
10 x	1.3 mm. diameter terminal pins

1 x 10 k trimming potentiometer (horizontal, 10mm basic grid)

and in surface-mounted format:

1 x	BC848B transistor or the like
1 x	TA 78L05F voltage regulator
1 x	1.0µF / 35V tantalum
1 x	4.7µF / 25V tantalum
1 x	10µF / 20V tantalum

all resistors and capacitors surface-mounted (1206/0805 format)

1 x	27Ω
2 x	100Ω
1 x	680Ω
4 x	1kΩ
1 x	2.7kΩ
4 x	10kΩ
1 x	1MΩ
1 x	120nF
2 x	1nF
3 x	10nF

7. LITERATURE REFERENCES

[1] Carsten Vieland, DJ4GC: UHF and SHF Broadband Mixers, VHF Communications 1/1989, pp. 39 - 45

[2] Detlef Burchard: Linear Signal Rectification (Part 1) VHF Communications 3/1994, pp.168 - 179

Wolfgang Schneider, DJ8ES

VHF, UHF and SHF Measuring Methods Using a PC

Part-3: 0.9 - 1.5 GHz Synthesizer

The frequency synthesizer can be thought of as one of the cornerstones in the structure of an amateur radio enthusiast's measuring equipment. Even just a 23cm signal to balance the pre-amplifier, an oscillator for the new 2m mixer module. All the frequencies which are of interest to amateur radio enthusiasts should be covered, at the lowest possible cost.

It is obvious that all these wishes can not be granted right away with just one piece of equipment. At least, not at a reasonable cost and with the measurement options normally available!

1. GENERAL

The following article, "0.9 - 1.5 GHz Synthesizer", describes the core of such a unit, the tunable oscillator (VCO) with the phase control circuit (PLL). In addition to the VCO, the synthesizer module and its programming are of vital importance in this context (Fig.1).

Other modules required, such as mixer assemblies for additional frequency ranges and PIN diode controllers to adjust the output power, will be the

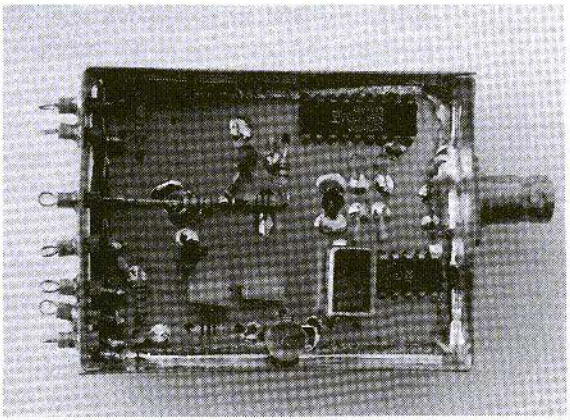


Fig.1: Experimental Rig for 0.9 - 1.5 GHz Synthesiser

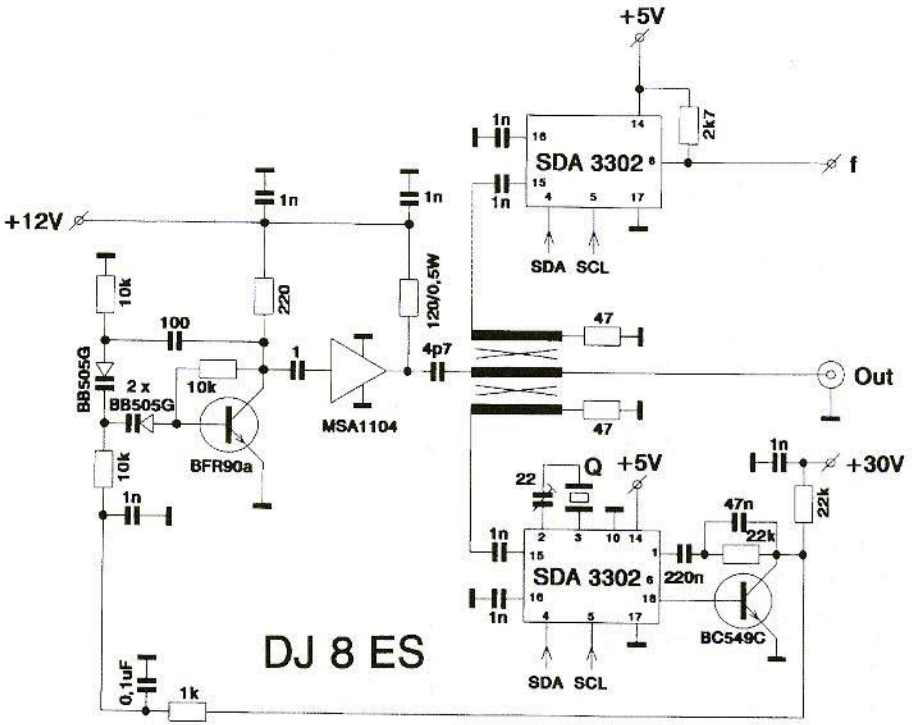


Fig.2: Circuit Diagram for 0.9 - 1.5 GHz Frequency Synthesiser

subject of articles to be published in future editions of VHF Communications.

2. CIRCUIT

The 0.9 - 1.5 GHz synthesizer was created on the basis of the FM-ATV transmitter for the 23cm band [1], details of which were published at that time. The only new feature is the SDA3302 programmable synthesizer module in the circuit (Fig.2).

The tunable oscillator (VCO) covers the entire frequency range, with a tuning voltage of +30V, in one sweep. The article referred to above contains any details required in connection with the assembly and operation of the circuit.

The frequency information is transferred to the integrated circuit through a special log on a 2-conductor bus (I^2C bus). The lines distinguish between CLOCK and DATA.

Günter Sattler (DJ4LB), among others, has made the functioning of such synthesizer modules clearer for us, as amateur radio enthusiasts, in [2] and [3]. Fig.3 merely shows once again the

structure of the data elements for the programming of the SDA3302 as a synthesizer.

There is also an addition to the complete circuit here, in the shape of an MSA1104 broad-band amplifier. The output power is thus app. 50mW over the entire tuning range (Fig.4). Moreover, the amplifier acts as a buffer stage for varying loads at the output.

A further SDA3302 IC is wired up in the experimental rig for my own experiments, this time as a frequency divider. The I²C bus controls both circuits!

3. SOFTWARE

The entire data log is transferred to the SDA3302 PLL IC for each frequency setting. The I²C bus forms the link. In this way, the chip address and all frequency and control parameters are transferred to the module integrated within special start / stop conditions.

Address	1	1	0	0	0	A_1	A_0	0	A
Divider 1	0	N_{14}	N_{13}	N_{12}	N_{11}	N_{10}	N_9	N_8	A
		1024	512	256	128	64	32	16MHz	
Divider 2	N_7	N_6	N_5	N_4	N_3	N_2	N_1	N_0	A
	8	4	2	1MHz	500	250	125	62,5kHz	
Control 1	1	1	T_1	T_0	1	1	1	0	A
Control 2	0	0	0	0	0	0	0	0	A

A Acknowledge (log. 0)

N Frequency Divider
(z.B. 1296 MHz: N_{14} , N_{12} , N_8 = 1)

Chipadresse	A_1	A_0	CAU (Pin 10)
	0	0	0V
	0	1	offen

Funktion	T_1	T_0	
	0	0	PLL
	1	0	Divider

Fig.3:
Data Formats for Programming the SDA 3302 as a Freq Synthesiser

DJ4LB describes the details and, in particular, the temporal sequences for the data transfer very graphically in [2] and [3].

Another program is available which is

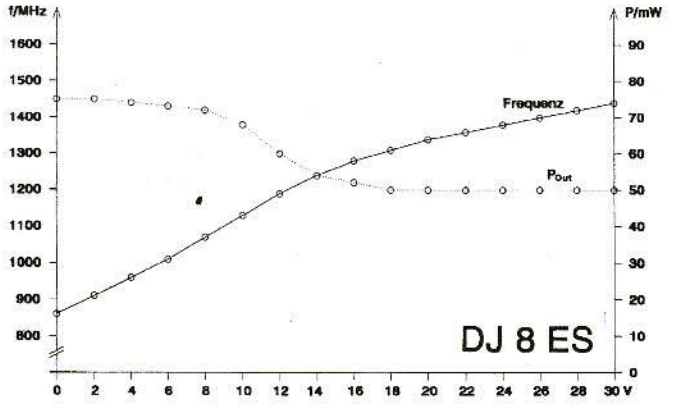


Fig.4:
Output Power and Frequency plotted against the Tuning Voltage

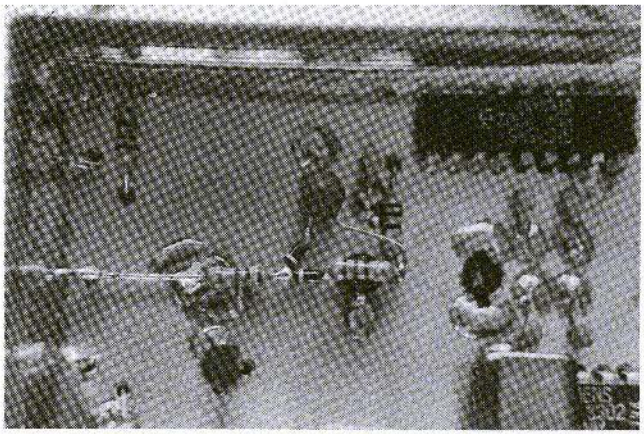


Fig.5: The Assembled VCO, shown greatly Magnified

suitable for 0.9 - 1.5 GHz frequency synthesisers, and is written in Turbo-Pascal 7.0. It contains all the components for the frequency synthesiser, but not for the frequency divider! Additional information required for operating the program is contained in the READ.ME file on the associated diskette.

Once started, the program sets the frequency of 1,296.0000 MHz as the default value. Other frequencies can be set through direct entry by means of the keyboard, or else using the cursor control keys. The minimum step width is 62.5 kHz, determined by the system.

4. ASSEMBLY INSTRUCTIONS

The entire circuit is constructed on an epoxy printed circuit board, coated on both sides, with the dimensions 54 x 72mm. It therefore fits into a standard tinplate housing with the dimensions 55.5 x 74 x 30mm. The holes are to be milled on the earth side using a 2.5mm drill. Only the earth contacts remain in existence.

The assembly of the VCO (Fig.5) and the subsequent broad-band amplifier is described in detail in [1]. As always in higher frequency ranges, special attention must be paid to creating a structure suitable for high frequencies. Short connecting wires are an absolute must!

Further details can be found in the equipment diagrams for the foil side (Fig.6) and the earth side (Fig.7). Moreover, the rig can be copied without any special problems for the person assembling it.

4.1. Components list

IC1	SDA3302 (Siemens)
IC2	SDA3302 (Siemens), optional
IC3	MSA1104 (Avantek)
D1, D2	Varicap diodes BB405G
T1	BFR96 (Valvo)
T2	BC549C (Valvo)
4	4 MHz crystals (HC18U or HC25U)

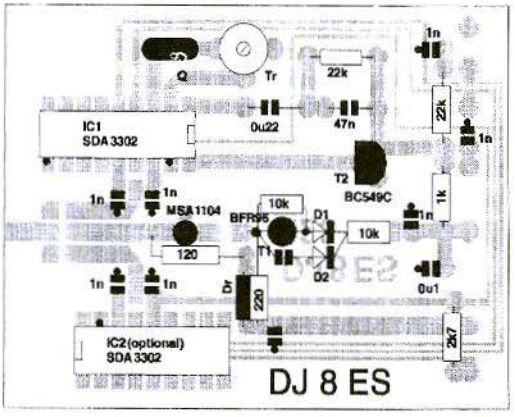


Fig.6:
Only a few Components on the Foil Side

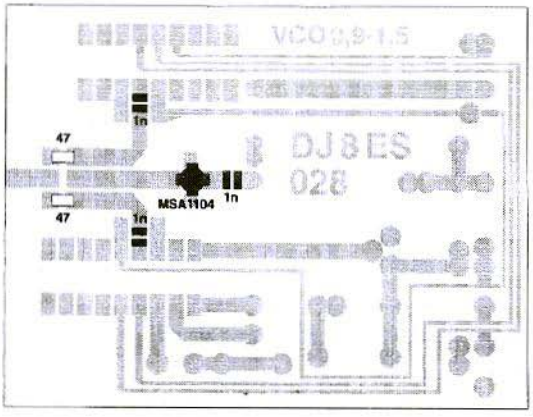


Fig.7:
Layout of Elements on Component Side

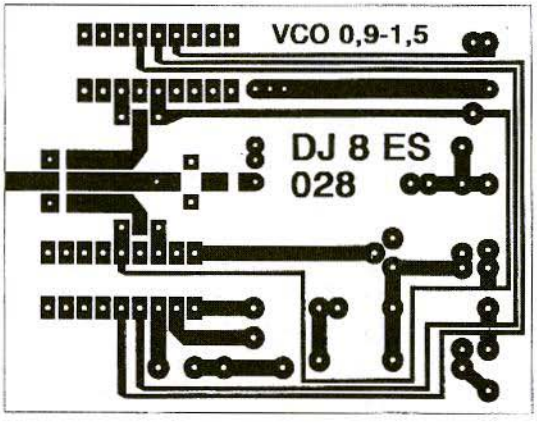


Fig.8:
DJ8ES 028 Printed Circuit Board. Reverse Side passing through Earth

Dr	λ/4 choke, 5 turns on 3mm diam rod, 0.1mm Cu lacquered wire
1	22pF foil trimmer Valvo, green
1	MKT capacitor 47nF, 7.5mm basic grid
1	MKT capacitor 0.1µF, 7.5mm basic grid
1	MKT capacitor 0.22µF, 7.5mm basic grid
1	carbon film 120Ω / 1W, 12.5mm basic grid
7	Teflon bushings
1	BNC jack UG290 A / U
1	tinplate housing 55 x 74 x 30mm.
1	PCB DJ8ES 028

1/8 Watt, 10mm basic grid resistors

1	220Ω
1	1kΩ
1	2.7kΩ
3	10kΩ
3	10kΩ
2	22kΩ

Ceramic disc capacitors, 2.5mm basic grid

1	100pF ceramic disc
7	1nF ceramic disc

And in SMD format
(1206 / 0805 construction)

2	47Ω
3	1nF

4.2. Putting into operation

The assembly group forming the 0.9 - 1.5 GHz frequency synthesiser must operate as soon as the operating voltages: + 5V (PLL), + 12V (VCO with amplifier stage) and + 30V (tuning voltage) are applied. A power level of app. 50mW (cf. Fig.4) and a frequency somewhere between 0.9 and 1.5 GHz can now be measured at the output jack.

The PC is now connected up. The Centronics adapter card described in Part 1 acts as interface. In this connection, d7 is the data line (SDA) and STROBE is the clock (SCL).

The standard address for the Centronics interface is LPT1. For other ports, the data can be adapted in the SYNTHESI.CFG file.

The READ.ME file on the diskette has additional information, especially with regard to installation. It should be read before the equipment is put into operation.

If the SYNTHESI.EXE program is now started, the frequency 1,296.0000 MHz must be set at the output of the assembly. Fine balancing can be carried out using the 22pF trimmer at pin 2 of IC1 (SDA 3302). A "Help" function is available through function key F1, as for the mW meter.

5. LITERATURE REFERENCES

[1] Wolfgang Schneider DJ 8 ES (ex. DD2EK); FM-ATV Transmitter for the 23cm Band
VHF Communications, no. 1/89, pp. 25-30

[2] Günter Sattler DJ4LB; SDA 3202 - New PLL-IC up to 1.5 GHz
VHF Communications 1/86, pp.18-22

[3] Günter Sattler DJ4LB; Crystal-Stable VCO Frequencies for ATV Processing
VHF Congress Weinheim 1991
Congress Proceedings, pp. 173

Note on Series of Articles:

The aim of the series of articles on VHF, UHF and SHF measuring methods using a PC is to enable us amateur radio enthusiasts to gain entry into this new and interesting area of discussion.

After the initial preparations and practical tests (cf. Centronics interface, mW meter and synthesiser), the next step is the development of a universal measuring apparatus for the amateur radio enthusiast.

This PC-controlled measuring apparatus for the 10 - 1,400 MHz frequency range combines the following functions:

- Synthesiser
- Wobbler
- mW meter and
- Spectrum analyser

Issues 2 and 3/97 of VHF Communications will contain a complete description of the assembly of all the elements.

In addition, the experimental mW meter and synthesiser set-ups already presented are being revised and turned into a more efficient version of what is a constituent part of the measurement equipment.

Thus, for example, the resolution in the µW range for the mW meter has been increased by two powers of ten, while the output power in the synthesiser has been largely kept constant, and the frequency range has been extended to cover the necessary minimum of 700 - 1,400 MHz.

Wolfgang Schneider, DJ8ES

VHF Communications Magazine on the World Wide Web

Please note that effective April 1st 1997 the VHF Comms WWW site will no longer be available at Eolas

The VHF Comms WWW site is now:

http://www.clearlight.com/~vhfcomm

Wolfgang Schneider, DJ8ES

VHF, UHF and SHF Measuring Methods Using a PC

Part- 4: High-Frequency Test Rig for up to 1.4 GHz

Following the introduction to the subject of VHF, UHF and SHF measuring using a PC, we now come to the real focal point of this series of articles - the development of a high-frequency test rig for up to 1.4 GHz.

Specifically, this means a frequency synthesiser, an mW meter, a wobbler and a spectrum analyser, combined into a measuring apparatus.

The result of all this is no miracle machine, but with minimal use of hardware a high-frequency test rig for up to 1.4 GHz can be created which makes interesting additional measuring options available for us radio amateurs.

1. CONCEPT

The PC takes over control of the individual assemblies (Fig.1) and of plotting the test results on the screen. A "486", such as is common nowadays, or

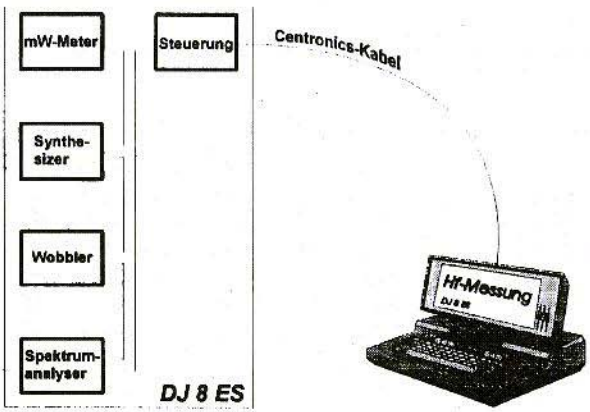


Fig.1: The PC Controls all Functional Units *Steurung* = Control, *Kabel* = Cable, *Messung* = Measurement

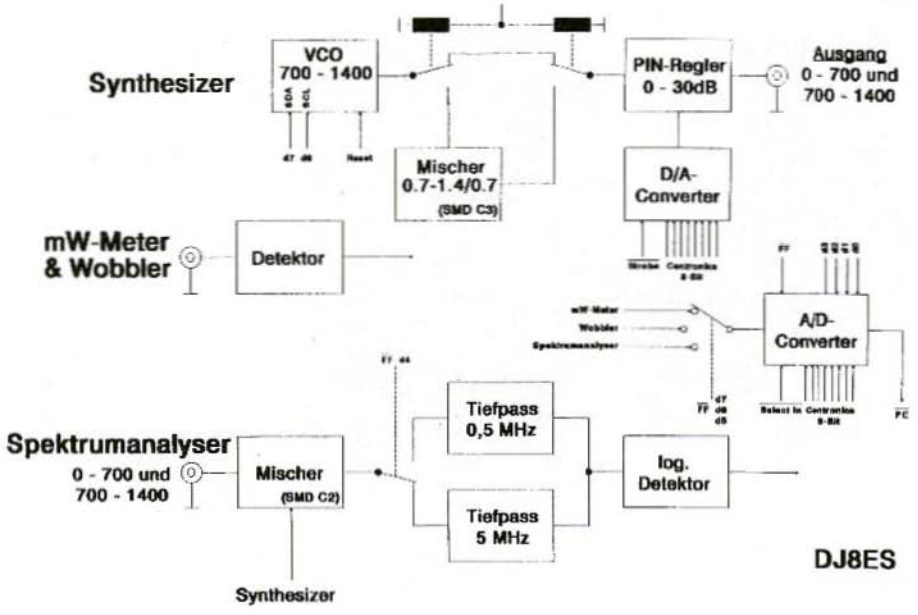


Fig.2: Automated Logic Diagram of High-Frequency Test Rig up to 1.4 GHz *Und* = And, *Detektor"* = Detector, *Mischer* = Mixer, *Tiefpass* = "Band pass, *Regler* = Controller, *Log. Detektor* = Logarithmic detector, *Ausgang* = Output

even a "386" with a hard disk and a colour monitor, can meet the requirements.

The interface between the PC and the hardware is provided by a Centronics printer interface (e.g. LPT 1), which many people will have already.

The automated logic diagram (Fig.2) shows the individual assemblies and their inter-connections.

The complete hardware consists of the following units:

- VCO with PLL (700 - 1,400 MHz)
- Mixer with LO (10 - 700 MHz)
- PIN diode controller
- Diode detector
- Analogue / digital converter
- Mixer with logarithmic intermediate-frequency amplifier

The measuring apparatus referred to at the start can be created through a suitable combination of these assemblies:

- mW meter: Diode detector and A / D converter
- Synthesiser: VCO and PLL, mixer and LO, PIN diode controller
- Wobbler: VCO and PLL, mixer and LO, PIN diode controller, diode detector and A / D converter

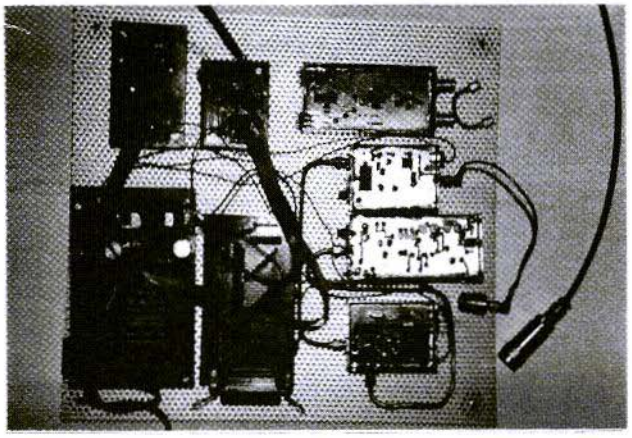


Fig.3: The High-Frequency Test Rig in Experimental Form

– Spectrum analyser: VCO and PLL, mixer and LO, PIN diode controller, mixer and logarithmic intermediate-frequency amplifier and A / D converter

These relationships and the circuits will be dealt with more specifically in the appropriate section. Thus, for example, the inter-action of the diode detector and the A / D converter in the mW meter will be described separately.

2. PC INTERFACE

The standard equipment for the Centronics printer interface includes an 8-bit data output, a 5-bit input capacity and also 4 output lines. A comprehensive description explaining the functioning and, above all, the control of this interface can be found in Part 1 of this series of articles [1].

The only additional information to be given at this point is the pin occupancy layouts (not completely identical) of the 25-pin and 36-pin plug connections on the lines which are relevant for us.

Connection	Pin (24)	Pin(36)
Data 1	2	2
Data 2	3	3
Data 3	4	4
Data 4	5	5
Data 6	5	5
Data 7	8	8
Data 8	9	9
Strobe	1	1
Auro Feed (FF)	14	14
Reset	31	16
Sel In	36	17
PE	12	12

2.1. Circuit Description

Controlling all the test rig hardware requires more lines than are available in the Centronics interface. This applies both to the control of the individual

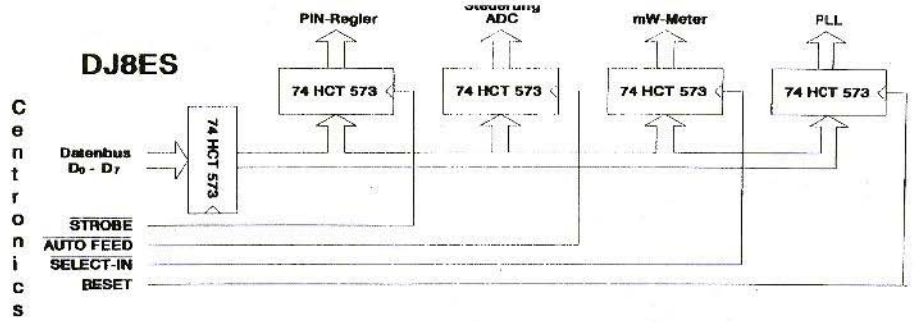


Fig.4: Interface Card for Connection to Centronics Interface
***Datenbus* = Data bus, *Regler* = Controller, *Steurung* = Control**

assemblies, e.g. the A / D converter, and to the lines connecting the units to each other.

4 type 74HC573 data latches distribute the data (Fig.4). The control data from the PC are deposited in the associated latch by means of a transfer pulse. An additional IC 74HC573 acts as a bus drive. The blocking-off capacitors (100 nF) for the 5-V operating voltage are in SMD format and are soldered directly onto the individual IC pins on the underside of the board.

2.2. Assembly Instructions

The double-sided interface card boards (DJ8ES 029) have only a Centronics socket, 5 74HC573 data latches and the associated rod strips for the internal wiring of the rig (Fig.5). The data bus is through-hole plated with short pieces of wire.

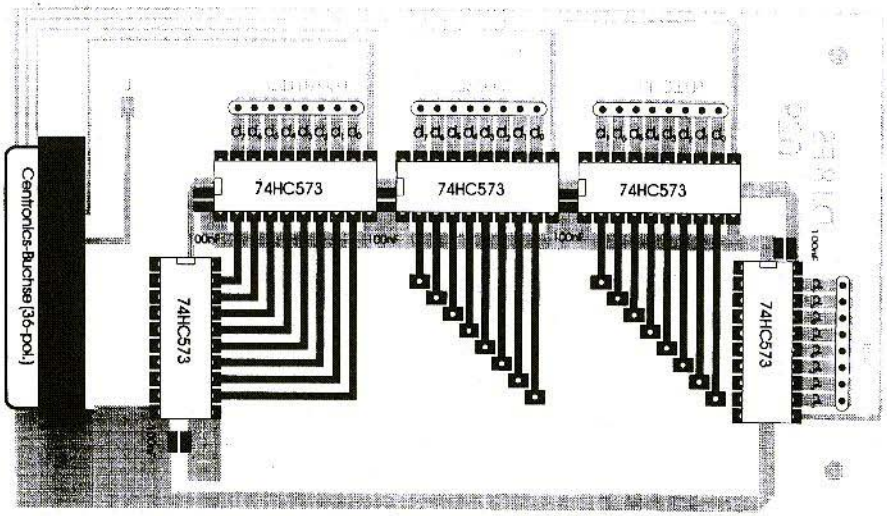


Fig.5: Component Overlay for Interface Card; *Buchse* = Socket, *Pol* = Pin

of stability and secondly to guarantee a good earth connection.

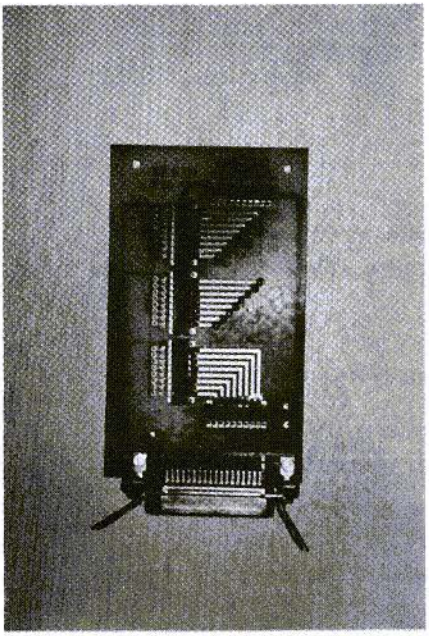


Fig.6: **Prototype Interface Card**

It is also important that the Centronics socket is connected to the board by M3 x 10 screws (Fig.6), firstly for reasons

2.3. Parts List

5 x 74HC573 5 x 100 nF (SMD, model 1206) 1 x Centronics socket (print model) 4 x rod strips (8-pin) 2 x M3 screws (10 mm. long) with nuts 3 x solder posts (1.3 mm.) c/w plug 1 x DJ8ES-029 board

3. FREQUENCY SYNTHESISER

As has already been seen in the automated logic diagram (Fig.2), the complete frequency synthesiser consists of three assemblies; VCO with PLL, mixer and PIN diode controller. When these are inter-connected, the combination covers the frequency range from 10 MHz to 1,400 MHz. The output level here can be adjusted between 10 mW (+ 10 dBm) and 10 W (-20 dBm).

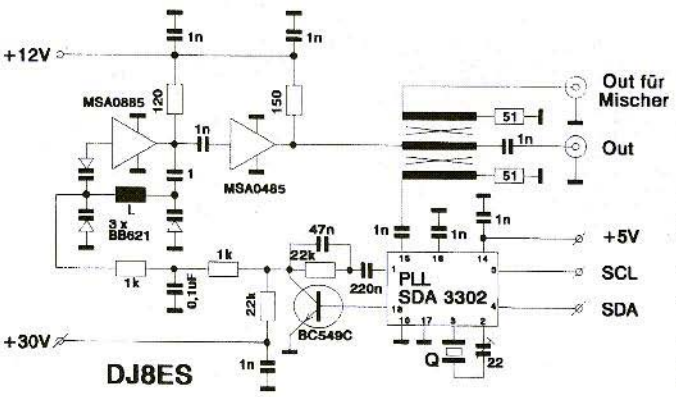


Fig.7: Wiring Diagram of 700 MHz - 1,400 MHz VCO
Für Mischer **= For mixer**

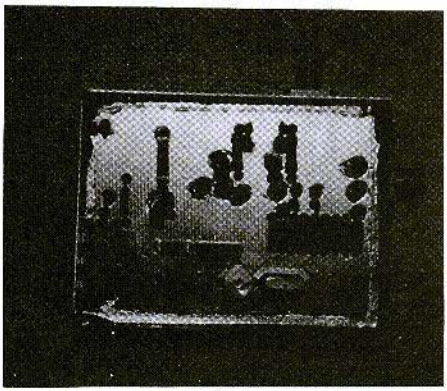


Fig.8: VCO Prototype with PLL

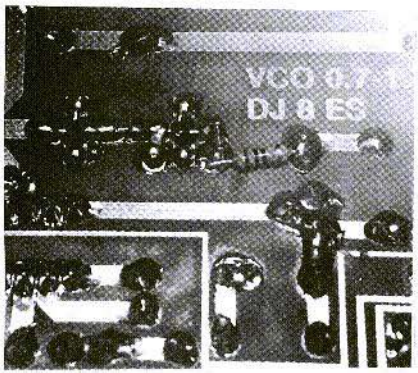


Fig.9: Magnified View

3.1. VCO with PLL

3.1.1. Circuit Description

The VCO, with a MSA 0885, spans the frequency range from 700 MHz to 1,400 MHz. The combination of three BB621's and the inductive resistor, L, is used for tuning. The signal then passes through the amplifier stage (equipped with an MSA 0485) and achieves a good 20 mW of output power (Fig.7).

The VCO has a special output of app. -10 dBm, which avoids saturating the mixer and thus creating unnecessary inter-modulation products.

The SDA 3302 component, familiar from TV engineering, acts as a control circuit (PLL). This makes tuning steps of 62.5 kHz possible in the above-mentioned frequency range.

The frequency data required are serially transferred to the PLL module from the PC through an I2C bus (SDA = data, SCL = clock).

3.1.2. Assembly Instructions

The complete circuit is assembled on a two-sided coated epoxy board, with dimensions of 54 mm. x 72 mm.. It thus fits into a standard tinplate housing, dimensions 55.5 mm. x 74 mm. x 30 mm. (Fig.8).

Drill-holes should be cut out on the earth side with a 2.5 mm. drill. Only the earth contacts are to remain!

The assembly of the VCO and the subsequent broad-band amplifier has been described in detail by DF 9 IC in [2]. The frequency is essentially determined by the length of the inductive resistor, L, and fine calibration is also possible, through a slight bending of the wire strap.

The BB 621 tuning diodes are flush with the surface of the board (Fig.9)! All additional details can be taken from the components diagrams (Fig's.10, 11).

As always with relatively high frequencies, special attention should be paid to an assembly suitable for high frequency - short connection wires are an absolute must! This can not be said too often.

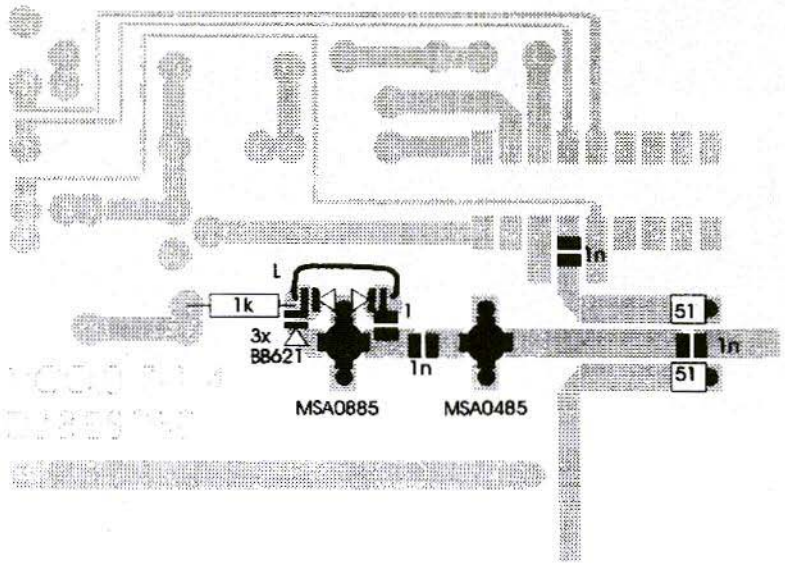


Fig.10: Components on Foil Side of VCO

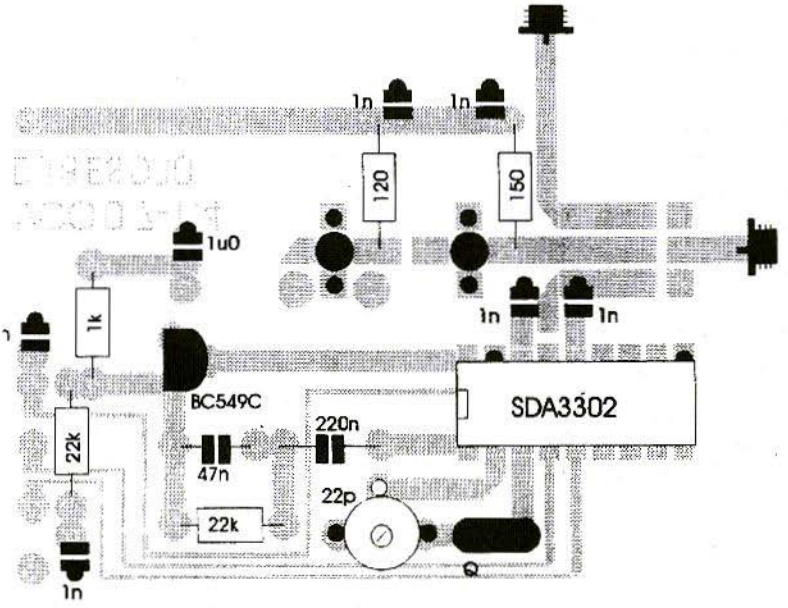


Fig.11: Components on Earth Side of VCO

Fig.12:
Prototype Mixer / LO Assembly

3.1.3. Parts List

1 x	SDA 3302 (Siemens)
1 x	MSA 0885 (Avantek)
1 x	MSA 0485 (Avantek)
3 x	BB 621 capacitance diodes
1 x	BC 549C (Valvo)
1 x	4 MHz crystal HC18U/HC25U
1 x	22-pF foil trimmer (Valvo, green)
1 x	47-nF MKT capacitor 7.5 mm. basic grid
1 x	0.1-µF MKT capacitor 7.5 mm. basic grid
1 x	0.22-µF MKT capacitor 10 mm. basic grid
1 x	120Ω / 1 W, carbon film resistor in 12.5 mm. basic grid
1 x	150Ω / 1 W, carbon film resistor in 12.5 mm. basic grid

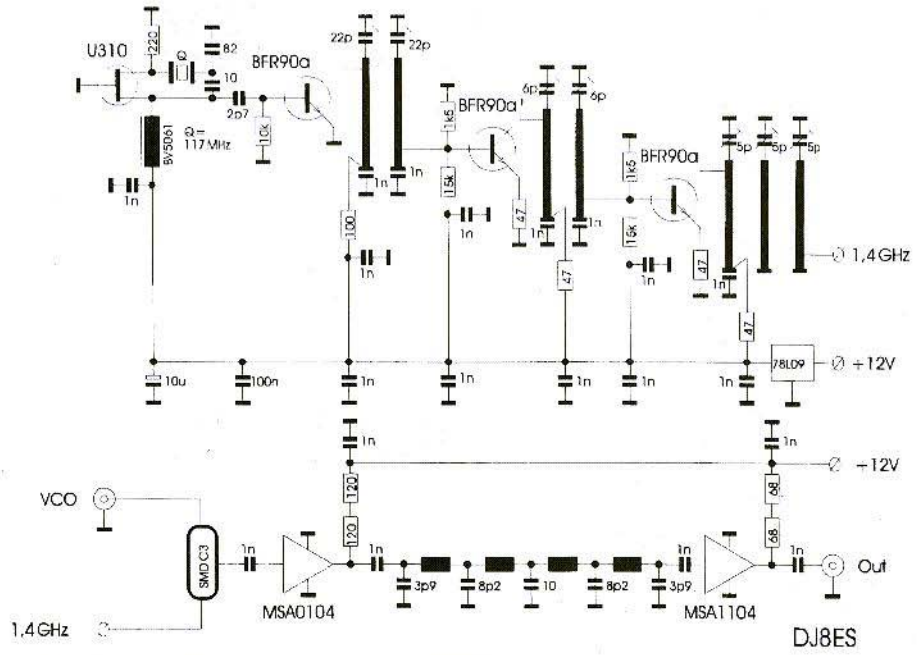


Fig.13: Circuit Diagram of 10 MHz - 700 MHz Mixer

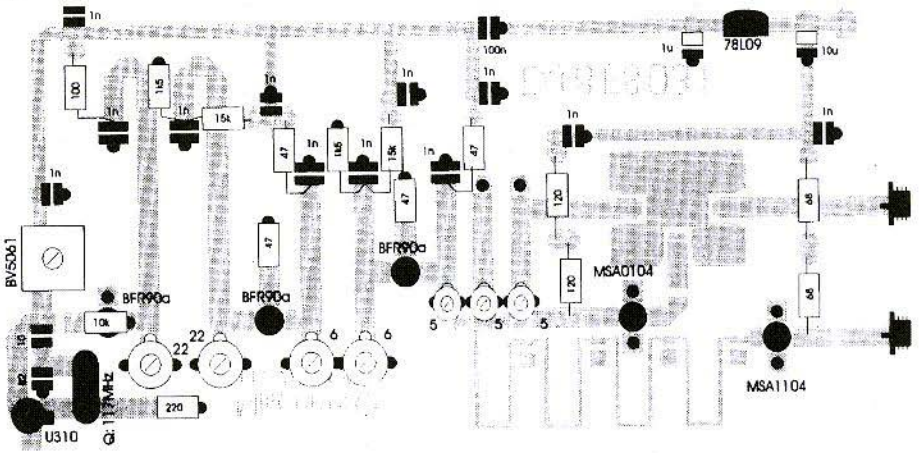


Fig.14: Mixer Components Diagram

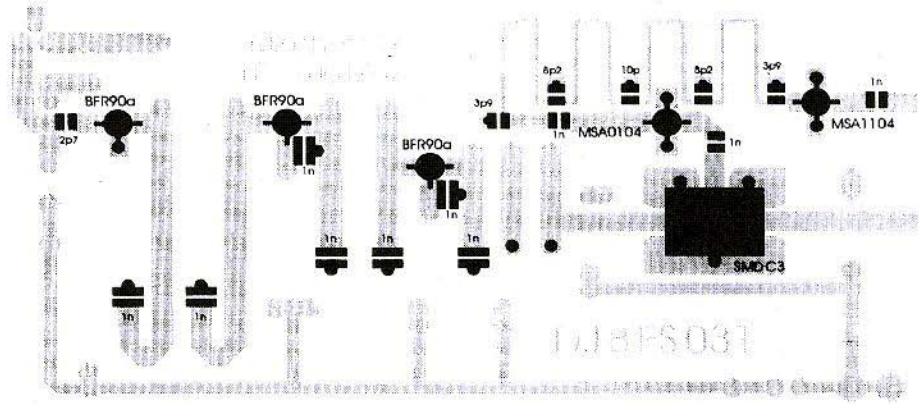


Fig.15: Components on Foil Side Mixer

1 x	tinplate housing 55 x 74 x 30 mm.
1 x	wire strap, 15 mm. long CuAg Θ 1 mm. (see text)
2 x	SMA flanged bushes (4-hole)
5 x	Teflon bushings
1 x	DJ8ES-030 board

1/8 Watt resistors, 10 mm. basic grid

2 x	1 k
2 x	22 k

Ceramic Capacitors 2.5mm Grid

6 x	1 nF

and in SMD format (model 0805 or 1206)

2 x	51Ohm
1 x	1 pF
3 x	1 nF

3.1.4. Putting into Action

The VCO needs an operating voltage of + 12V / 115mA and + 5V / 35mA, together with a tuning voltage of +30V.

First the tuning range of the VCO should be tested. For this purpose, the control circuit is disconnected (collector BC 549C). With a tuning voltage between 0 V and 30 V, the oscillator must cover the frequency range 700 MHz to 1,400 MHz and more. The output power is an almost constant 20 mW over the entire frequency range.

3.2. Mixer / LO

So that the lower frequency range can also be used, a mixer / LO module is wired up subsequent to the VCO (Fig.12). This provides functional access to the range between 10 MHz and 700 MHz.

3.2.1. Circuit Description

The local oscillator required (117 MHz) is created with the oscillator circuit which is normal in amateur radio circles, using a U310. The subsequent twelvefold circuit with 3 x BFR 90 A (Fig.13) gives an output power of app. 20 mW at 1,404 MHz.

An SMD-C3 serves as a mixer module, followed by an MMIC MSA 0104, the 9-pin deep-pass filter, and an MSA 1104 as an additional amplifier. A level of max. 50 mW can be expected at the output to control the PIN diode controller over the range from 10 MHz to 700 MHz.

3.2.2. Assembly Instructions

The mixer with the LO is also created on a double-sided coated epoxy board - the dimensions are 54 mm. x 108 mm.. The circuit thus fits into a standard tinplate housing with the dimensions 55.5 mm. x 111 mm. x 30 mm..

The through-platings on the ring mixer (SMD C3) are of 1.5 mm. CuAg wire, while 3 mm. long hollow rivets have been used for the other platings.

Otherwise, the type and manner of assembly are the same as those for the VCO assembly. The position of the assembly elements can be taken from the components diagrams (Fig.14 and Fig.15) for the foil side of the DJ8ES 031 board.

The SMD-C3 mixer should be soldered on only following the complete calibration of the frequency multiplier stages. The assembly can thus be put into operation faster and more easily.

3.2.3. Parts List

1 x	MSA 0104 (Avantek)
1 x	MSA 0304 (Avantek)
1 x	78LO9, voltage controller
1 x	U310 (Siliconix)
3 x	BFR 90A (Valvo)
1 x	SMD C3, mixer
1 x	117 MHz crystal, series resonance, HC18-U or HC25-U
1 x	BV 5061, Neosid, 0.1 µH blue / brown
3 x	5 pF Sky-Trimmers (green)
2 x	6 pF foil trimmers (grey)
2 x	22 pF foil trimmers (green)
7 x	1 nF trapezoid capacitors

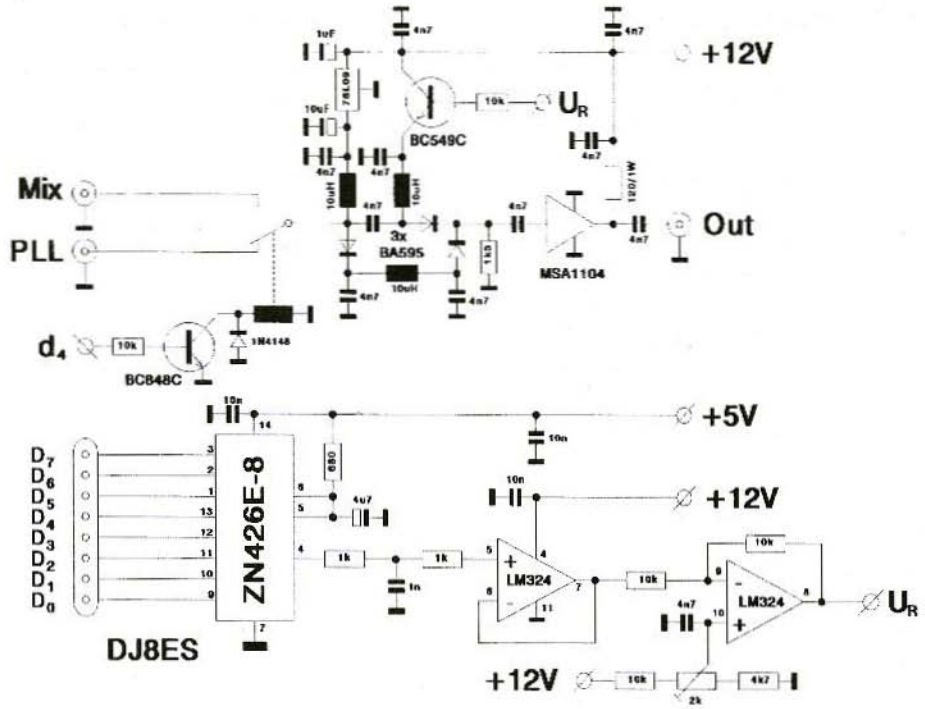


Fig.16: Pin Diode Controller

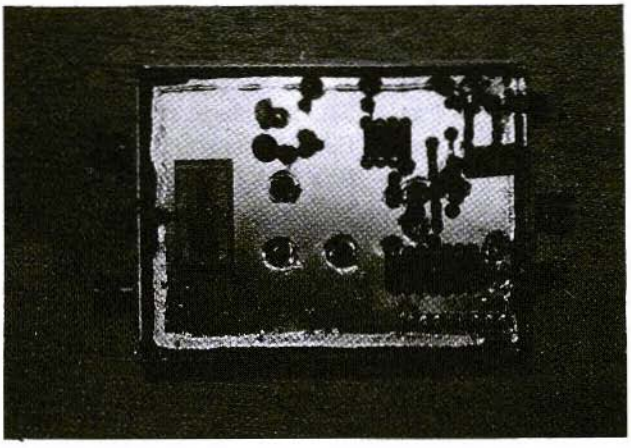


Fig.17:
Pin Diode Controller
Prototype

1 x	1 µF / 20 V tantalum electrolytic capacitor
1 x	10 µF / 20 V tantalum electrolytic capacitor
1 x	tinplate housing 55 x 111 x 30 mm.
2 x	SMA flanged bushes (4-hole)
16 x	hollow rivets, length 3 mm.
1 x	Teflon bushing
1 x	DJ8ES-031 board

1/8 Watt resistors, 10 mm. basis grid

4 x	47 Ohm
2 x	68 Ohm
1 x	100 Ohm
2 x	120 Ohm
1 x	220 Ohm
2 x	1.5 k
1 x	10 k
2 x	15 k

Ceramic capacitors, 2.5 mm. basic grid

1 x	10 pF
1 x	82 pF
7 x	1 nF
1 x	100 nF

All SMD capacitors (model 0805)

1 x	2.7 pF
2 x	3.9 pF
2 x	8.2 pF
1 x	10 pF
3 x	1 nF

3.2.4. Putting into Operation

With an operating voltage of + 12 V, the assembly picks up about 160 mA of current. Only 50% of this is allocated to the two amplifiers MSA 0104 and MSA 1104.

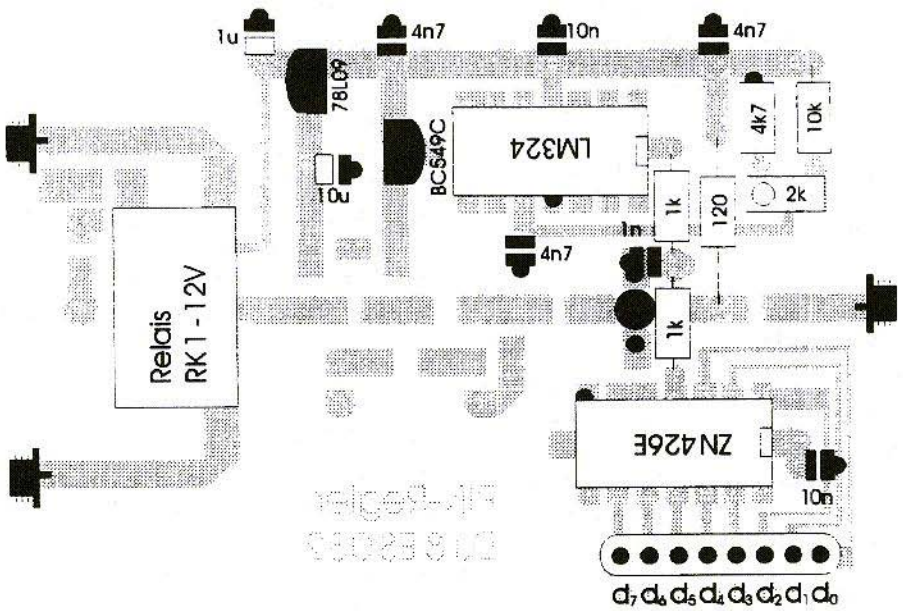


Fig.18: Pin Diode Controller Components Diagram
***Relais* = Relay**

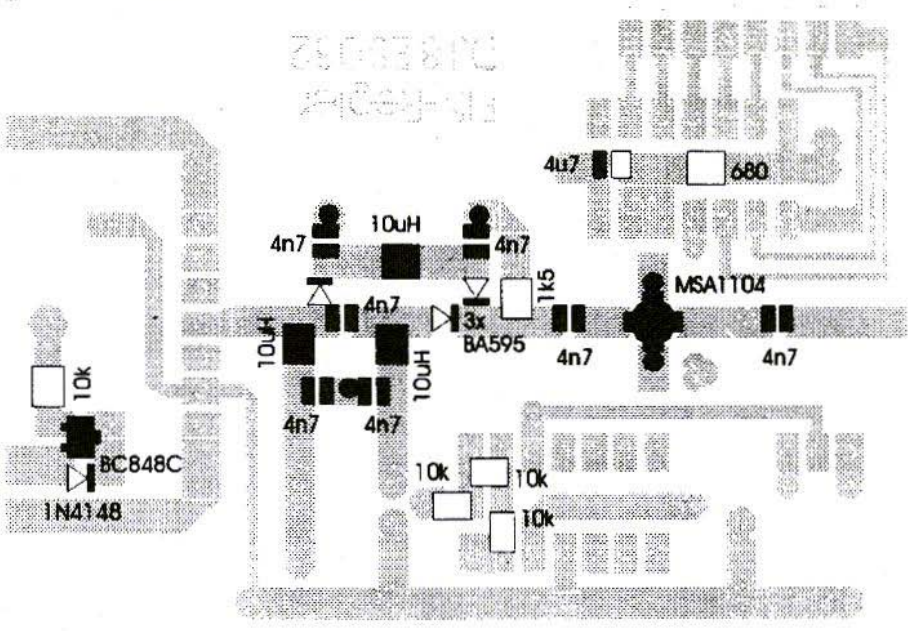


Fig.19: Foil Side Components

After the oscillator (U310 with a BV5061 coil) has been made to oscillate at 117 MHz, the frequency multiplier is calibrated step by step. With the VCO connected up, the mixer achieves an output power of max. 50 mW in the range between 10 MHz and 700 MHz.

3.3. Pin Diode Controller

3.3.1. Circuit Description

A circuit which was previously standard in television engineering is used as the pin diode controller (Fig.16). Three SMD diodes (BA 595) thus control the output power of the synthesiser at the desired value.

The control circuit is voltage-controlled and is controlled by the PC by means of a D / A converter (ZN 426E). Thus with 8 bits, about 256 steps are generated in all in the 0 to 2.5 V range for every 10 mV.

Because of the circuit, a control value of "0 dez" corresponds to maximum output power. The maximum possible damping is obtained with "225 dez". Depending on the frequency, it is at max. 70 dB in the short-wave range and is still 30 dB at the upper frequency limit of 1,400 MHz (Fig.17).

3.3.2. Assembly Instructions

The pin diode controller is created on a double-sided coated epoxy board. The dimensions are 54 x 72 mm.. The circuit thus fits into a standard tinplate housing which has dimensions of 55.5 mm. x 74 mm. x 74 mm. x 30 mm..

The position of the assembly elements can be seen in Fig.18 for the components side, and in Fig.19 for the foil side, of the DJ8ES 032 board. In other respects, the same assembly instructions apply here as for the assemblies already described.

3.3.3. Parts List

1 x ZN 426E-8, D / A converter
1 x MSA 1104 (Avantek)
1 x LM 324
1 x 78L09, voltage controller
1 x BC549C
1 x BC848C (SMD)
1 x 1N4148 (SMD)
3 x BA595 (SMD)

1 x 2 kΩ, trimmer
(vertical, 2.5 mm. basic grid)
1 x 120 Ω / 1 W
12.5 mm. basic grid
1 x 1 µF / 35 Vtantalum
1 x 10 µF / 20 Vtantalum
1 x RK 1-12V, relay (Matsushita)
3 x SMA flanged bushes (4-hole)
1 x post strip (8-pin)
3 x Teflon bushings
5 x hollow rivets (3 mm. long)
1 x tinplate housing
55 x 74 x 30 mm.
1 x DJ8ES-032 board

1/8 Watt resistors, 10 mm. basic grid
2 x 1 k
1 x 4.7 k
2 x 10 k

Ceramic capacitors, 2.5 mm. basic grid
1 x 1 nF
3 x 4.7 nF
2 x 10 nF

and in SMD format:

3 x 10 µH chokes
1 x 4.7 µF / 25 V tantalum

SMD resistors and capacitors
(model 1206 or 0805)
1 x 680 Ohm
1 x 1.5 k
4 x 10 k
7 x 4.7 nF

3.3.4. Putting into Operation

The PIN diode controller needs two operating voltages: + 12 V / 65 mA for the analogue section and + 5 V / 10 mA to operate the ZN426E D / A converter.

For calibration, the spindle trimmer must merely be set in such a way that a high-frequency signal can be fed in and given maximum amplification. For this purpose, the data connections D0 to D7 must be connected to earth, which corresponds to a D / A converter output voltage of 0 V.

The entire assembly has a transit amplification of app. + 3 dB.

The output level can later be reduced to the desired value using the program.

4. LITERATURE REFERENCES

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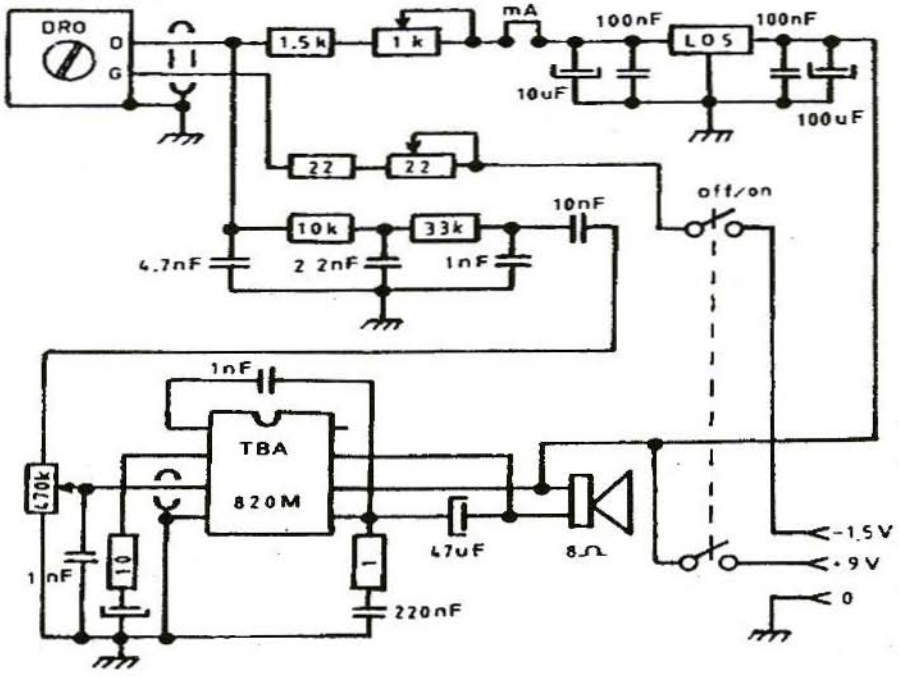
Please accept our apologies for an error which appeared in Fig.3 (page 3). The supplies at the bottom right-hand side of the diagram were incorrect. The corrected diagram is reproduced below.



Wolfgang Schneider, DJ8ES

VHF, UHF and SHF Measuring Methods Using a PC

Part 5: mW Meters, Wobblers and Spectrum Analysers

5. mW METERS

The mW meter can be used to measure power levels between 100mW (+20dBm) and 10µW (-20dBm). For this purpose, two functional units are used from the hardware range available.

The power level - or a voltage corresponding to the power level - is measured using the diode detector (1SS99) with an integrated 5W moving load.

This voltage must be suitably prepared for the PC - say, be digitised. The A/D converter is used as the second assembly here.

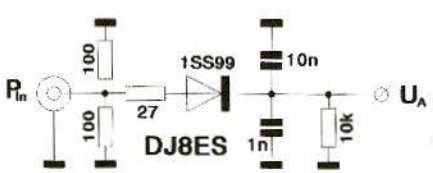


Fig.20: Diode Detector Circuit

5.1. Diode Detector

The diode detector has a dynamic range of over 50dB with a 1SS99. This high

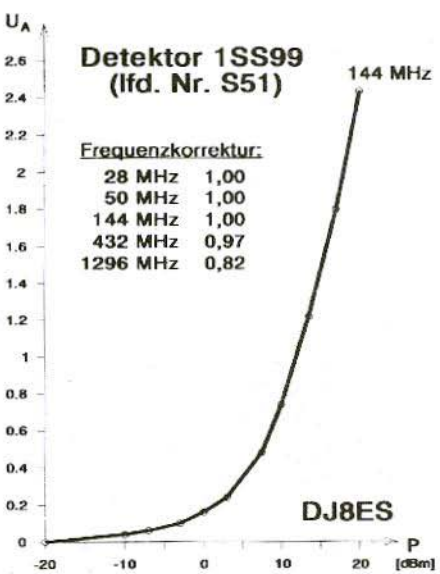


Fig.21: Output Voltage to Input Power Ratio;
Detektor **= Detector,** ***Lfd. Nr.*** **= Serial no.,** ***Frequenzkorrektur*** **= Frequency correction**

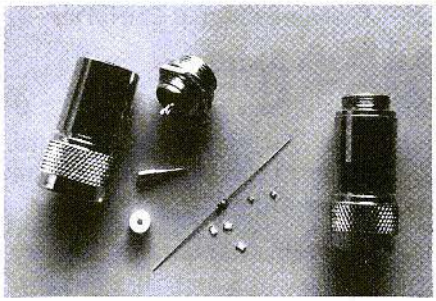


Fig.22: The BNC DetectorVersion

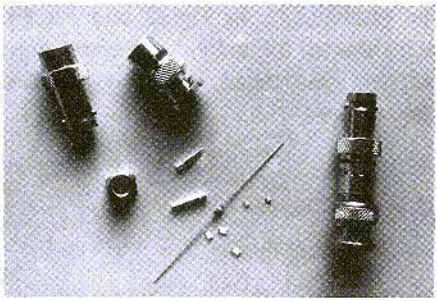


Fig.23: The N-Norm Detector

value naturally requires the circuit to be assembled to be suitable for radio frequencies! SMD components and short connecting wires where wired components are used are an absolute must.

Fig.20 shows the detector circuit; Fig.21 shows its output voltage, plotted against the measured input power in the range between 10mW (- 20dBm) and 100mW (+ 20dBm).

5.1.1. Assembly Instructions

The detector is inserted in the standard way, in the BNC version. As an air assembly, directly incorporated in a plug / jack, it obtains the best performance.

All the details for assembly have already been described - in Part 2 of this series of articles ("mW meters for short-wave to SHF"). Assembly in an N-plug is naturally also possible.

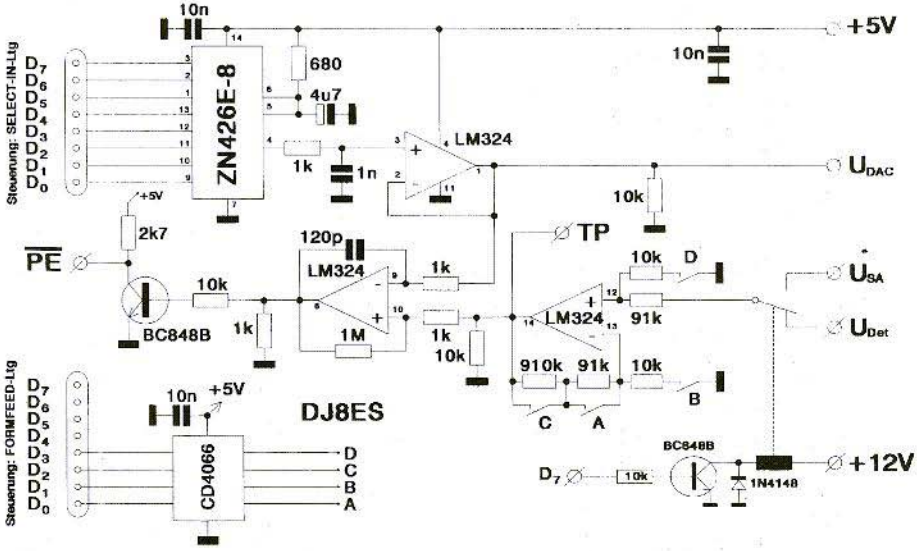


Fig.24: A / D Converter Circuit with Detector*Steurung* = Control

The photographs in Fig.22 and Fig.23 each show all the individual components and the associated, fully assembled detector head.

5.1.2. Component List

1 x 1SS99 diode
1 x UG 88/U BNC plug
(Alternative: 1 x N-plug (Aircom))
1 x UG 89/U BNC cable jack
(Alternative: 1 x micro-jack (2-pin))
1m. RG58U coax cable with suitable pin-and-socket connectors

SMD resistors and capacitors in 1206 format:

1 x 27Ω
2 x 100Ω
1 x 10kΩ
1 x 1nF
1 x 10nF

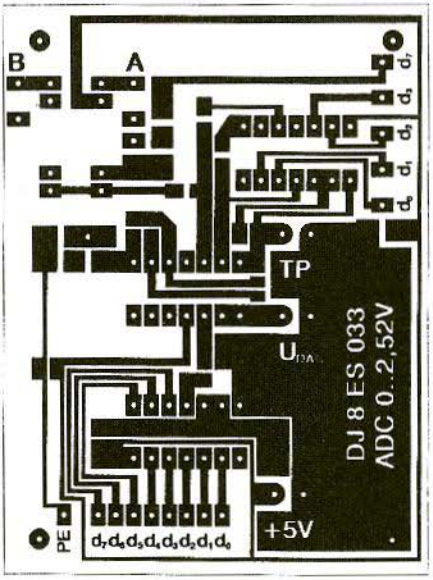


Fig.25: DJ8ES 033 PCB; A / D Converter

5.2. Analogue / Digital Converter

5.2.1. Circuit Description

A reference voltage between 0 and 2. V is generated in the analogue / digital integrated circuit from a pre-set 8-bit data word with a ZN426E (Fig.24).

The comparator compares this with the voltage to be measured. It gives the decision as to whether the reading is higher or lower than the reference voltage at the PE connection, in the form of a high or low level signal to the PC.

The method used to determine the measured voltage is that of successive approximation. In this way, the scoring logic in the program approaches the measurement result through a series of jumps.

So that usable measuring results can also be obtained in the lower, flat section of the detector diode characteristic curve, an operational amplifier is connected in series to the converter. This can be adjusted in stages, with regard to its amplification (x 0.1 / x 1 / x 10 / x 100). Depending on the

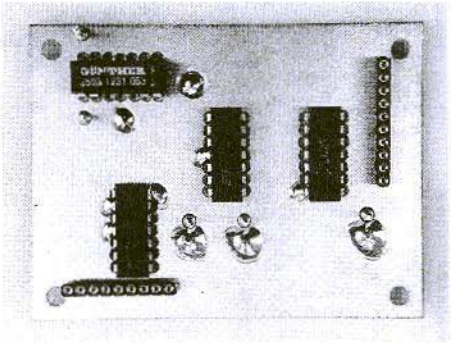


Fig.26: Components Side of Prototype DJ8ES 033

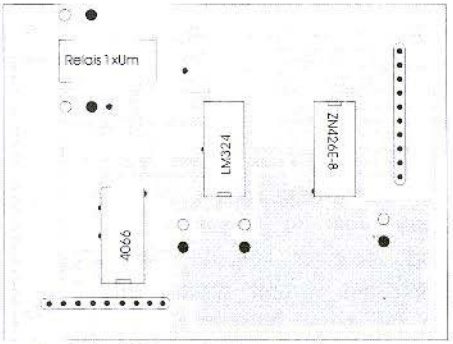


Fig.27: IC's and Connection Elements are mounted from the Earth Side; *Relais* = Relay

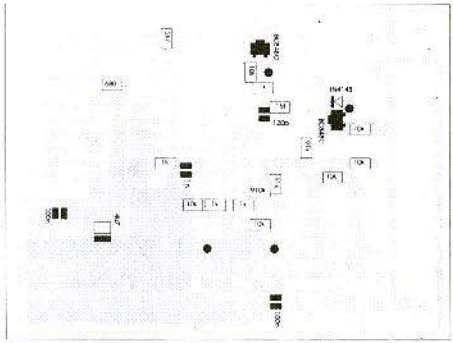


Fig.29: Tracks Side has only SMD Components

switching condition of the CD 4066, the input signal is thus always in the optimum range.

5.2.2. Assembly Instructions

The analogue / digital converter circuit is assembled on an epoxy board, copper-coated on both sides, with the dimensions 60 mm x 80 mm (Fig.25). IC's, relays and all the connection jacks and pins are mounted on the components side (Fig's.26 and 27). All earth connections are soldered onto this fully laminated side as well. The SMD components are soldered directly onto the individual tracks in accordance with Fig's.28 and 29.

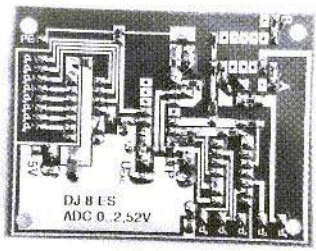


Fig.28: View of SMD Components on Tracks Side

5.2.3. Component List

1 x	LM 324 operational amplifier
1 x	ZN 426E-8 digital / analogue converter
1 x	4066 analogue switch
2 x	BC848 C, SMD transistors
1 x	LL4148, Mini Melf diode
1 x	Reed relay (1 x Um)
8 x	1.3mm terminal pins
2 x	10-pin socket terminal strips
1 x	4.7µF SMD electrolytic
1 x	DJ8ES 033 PCB

SMD resistors and capacitors are 0805 or 1206 format:

1 x	680Ω
4 x	1kΩ
1 x	2.7kΩ
5 x	10kΩ
2 x	91kΩ
1 x	910kΩ
1 x	1MΩ
1 x	120pF
1 x	1nF
1 x	10nF

5.2.4. Putting Into Operation

The data lines d0 to d7 for the A / D conversion are to be connected through a ribbon cable with the corresponding pins of the Selln-Latch on the interface card.

The PE pin is to be used to report back to the PC on the A / D conversion.

Lines d0 to d3 on the FormFeed-Latch are reserved for setting the amplification. Bit d7 of this port switches the analogue input over (A or B).

The diode detector is connected to input B.

The circuit should now be ready for operation, so its functioning can be tested using HFMESS software.

With a voltage of +5V, the current consumption of the analogue / digital converter assembly amounts to about 15 mA.

The final step is to measure the reference voltage of the A / D converter. The value should be 2.52V at pins 5 / 6, to the earth of the ZN426E. Any discrepancies have an influence on the correction factor, AU (cf. Section 10.13.).

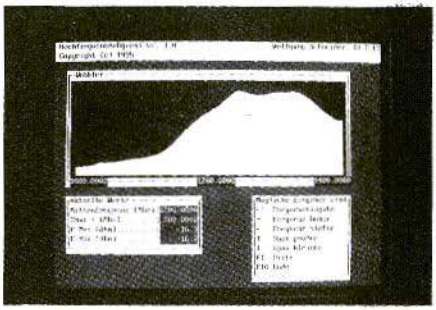


Fig.30: A Filter for ATV Applications at 23 cm as Test Object

6. WOBBLER

No additional circuit need be added for the functioning of the wobbler. The combination of frequency synthesiser, diode detector and A / D converter allows for wobble measurements over the full range between 10 and 14000 MHz.

The dynamic range of the wobbler thus results, on the one hand, from the output power of the synthesiser, and on the other hand, naturally, from the limiting sensitivity of the detector; in the given circuit, therefore, just 40dB.

The test object is merely looped in between the synthesiser and the diode detector for the measurement. The software does everything else.

Fig.30 shows the result of a wobble measurement in the range from 1000 to 1400 MHz. For this purpose, the entire range is traversed step by step, and for each frequency step the current level at the output of the test object is determined and plotted.

7. SPECTRUM ANALYSER

The only new assembly which comes up under the heading "Spectrum analyser" is a mixer with a logarithmic detector amplifier.

Only in combination with the frequency synthesiser does the complete spectrum

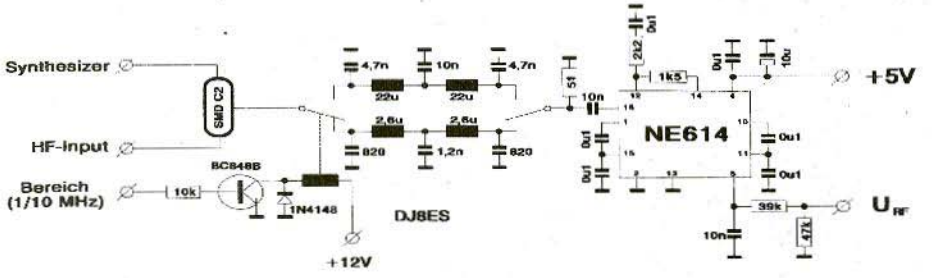


Fig.31: Wiring Diagram of Mixer with Logarithmic Display Amplifier; *Bereich* = Range

analyser emerge, for the frequency range from 10 to 1400 MHz.

7.1. Circuit Description

The mixer assembly with logarithmic detector amplifier operates on the direct mixing principle. The frequency range to be represented is traversed step by step and mixed down (Fig.31).

The two deep pass filters make two band widths possible: DC to 0.5 MHz, or broad-band DC to 5 MHz.

The logarithmic detector amplifier is created using an IC from FM technology (NE 614). Depending on the input level, the voltage meter output supplies a voltage between 1V and 4V; the dynamic range amounts to just 70dB.

The PC takes over this level information using the ADC assembly.

The voltage divider (39k / 47k) is provided at the output of the IC, to match the voltage range to the measuring range of the converter (0...2.5V).

7.2. Assembly Instructions

The mixer assembly with the logarithmic detector amplifier is also assembled on an epoxy board, copper-coated on both sides, with the dimensions 54 mm

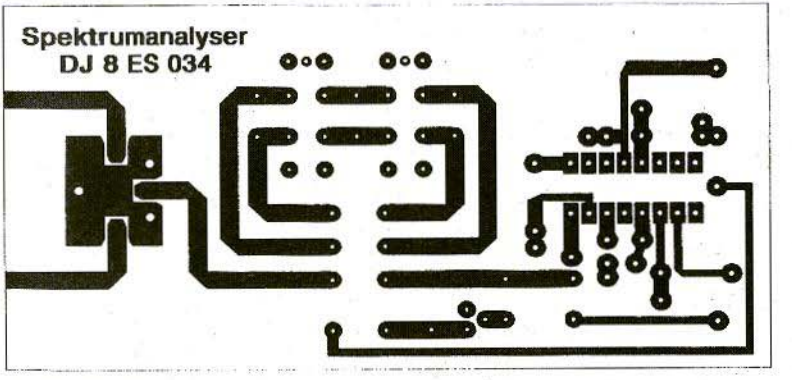


Fig.32: DJ8ES 034 Printed Circuit Board; Direct Mixer with Logarithmic Level Display; *Spektrumanalyser* = Spectrum Analyser

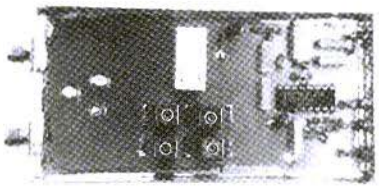


Fig.33: View of Prototype Mixer

x 108 mm (Fig.32). The circuit thus fits in a standard tinplate housing (55.5 mm x 111 mm x 30 mm) (Fig.33)

The coupling capacitors and the mixer are soldered on the foil side, all other components on the components side (Fig.34).

The earth feedthroughs are manufactured using silver-plated copper wire, with a diameter of 1.5 mm.

Operating voltages, the switch voltage for the filter conversion and the log. voltage output are connected by means of 1nF feedthrough capacitors. The radio-frequency connections are carried out using SMA connectors.

7.3. Component List

1 x NE 614
1 x BC549C transistor
1 x 1N4148 diode
1 x SMD C-2 mixer
1 x relay (2 x Um)
2 x BV5138 (2.6µH) Neosid ready-made filter
1 x BV5313 (22µH) Neosid ready made filter
4 x 1nF DF, solderable
6 x 0.1µF, RM 10, MKH
1 x 10µF / 35V tantalum
1 x tinplate housing, 55 x 111 x 30 mm
1 x DJ8ES 034 PCB

1/8 W resistors, 10 mm grid:

1 x 51Ω
1 x 1.5kΩ
1 x 2.2kΩ
1 x 10kΩ
1 x 39kΩ
1 x 47kΩ

Ceramic capacitors, 2.5 mm grid:

2 x 820pF
1 x 1.2nF
2 x 4.7nF
3 x 10nF

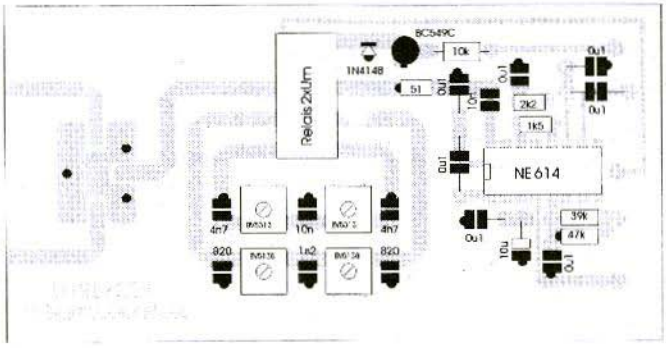


Fig.34: Components Plan; SMD Mixer and Coupling C's are mounted on Tracks Side;
***Relais* = Relay**

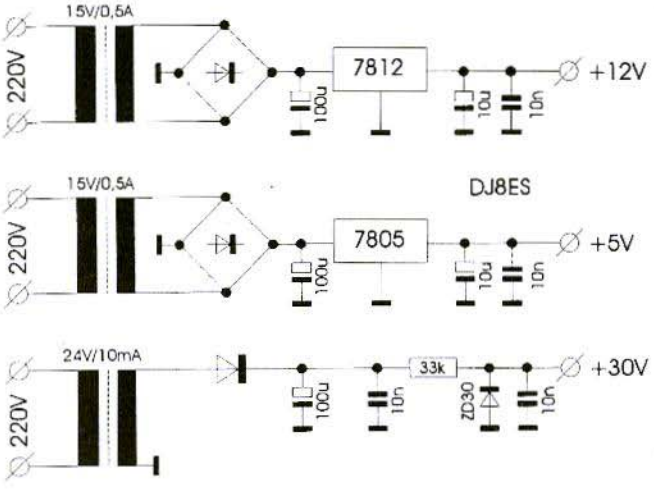


Fig.35: Example of Circuit for Power Supply

7.4. Putting Into Operation

The assembly requires two operating voltages: +5V / 3mA and, for the band width selection, +2V / 18mA.

The measurement output, U_{RF}, is connected to input A of the analogue / digital converter. The filter switching, 1 to 10 MHz, is determined by pin 4d on the FormFeed-Latch of the interface card.

The oscillator input of the mixer (LO) must not be saturated. The LO output can be held constant at +7dBm only from software version 3.0 onwards. Earlier versions require a 10dB attenuator between the synthesiser and the LO input.

Since the compression on the SMD C-2 mixer sets in as early as app. 100µW (-10dBm), a 10dB attenuator should also be connected in series to the radio-frequency input. The maximum usable input level thus rises to 1mW (0dBm).

The value MaxVoltSA for 0dBm for the software is set at 2.0V. The default value for MinVolt SA (-70dBm) is 0.4V.

Entries are to be matched in the file HFMESS.CFG if necessary (see Section 10.12.).

8. POWER SUPPLY

Three operating voltages are needed for the power supply (Fig.35):

±5V for digital section, PLL and A / D or D / A converter

±12V for switching relays, OP's, amplifier and transistor stages

±30V as tuning voltage for VCO

In the specimen unit, this power supply is assembled on a standard breadboard. Because the total current consumption is low, no heat sinks are required for the 78xx family of regulators.

9. INTER-CONNECTING INDIVIDUAL ASSEMBLIES

The individual assemblies are to be combined with one another depending on the application (mW meter, synthesiser, wobbler or spectrum analyser). E.g., simple switching relays are used here, as well as a coax relay, for the radio-frequency branch - users can decide the details for themselves.

For the prototype assembly, N-connectors were used for the external radio-frequency connections, and SMA connectors for the internal ones.

Other connections inside the equipment are carried out using single-row pin-and-socket connectors. Connections to the exterior are made using feedthrough capacitors (1nF).

10. SOFTWARE

It is frequently necessary to spend a lot on electronic components for operation and display in connection with measurement and test procedures. The mathematical preparation of the signals can also be very complicated.

The expense increases still further if interfaces also have to be provided with other equipment such as, for example, a printer.

Ideally, the computer can take over a whole series of tasks from a measuring instrument. It can be operated through the keyboard, and readings can be displayed numerically or even graphically on its screen.

Other equipment can be influenced through its interfaces - printers can be controlled, and in addition readings can be logged and put on paper.

Its capabilities for converting readings mathematically leave scarcely anything to be desired.

The various assemblies essentially use components which are highly compatible with a PC. Here, for example, there are I^2C bus circuits and µP-compatible AD / DA converters. The HFMESS software was developed so that this technology could be used as a whole.

The program controls the assemblies through the printer interface, which can be freely selected (LPT1, LPT2 or LPT3).

10.1. Operating Software

The program diskette contains the following files:

HFMESS.EXE is the main program itself. It can run on MS-DOS and IBM-DOS.

HFMESS.HLP contains help texts to guide the operator. They can be called up at almost all points during the running of the program, using the F1 function key.

HFMESS.CFG is used to pre-set necessary parameters (e.g. interface addresses). The data can be entered or changed using a standard text editor, or with EDIT.COM, supplied with MS-

DOS. The contents are individually listed in Section 10.12..

HFMESS.MNU is the list of the menu items available.

CALIBRI.BIN contains level settings from -10dB to +10dB, over the entire frequency range. This file is generated through the "Calibrate" routine (see main menu).

FEHLER.TXT shows the measured values per frequency in MHz for level discrepancies. This file is generated through the "Calibrate" routine (see main menu).

MWTABLE.TXT contains all the tables for the output calculation and calibration of the diode detector. This file is discussed again, in greater detail, in Section 10.13..

READ.ME contains current information on the software, and should be read before installation.

10.2. Hardware Requirements

The program requires a PC with a 286 processor, a 640-kbyte main memory and a VGA graphics card. However, a 386, or better still a 486, is preferable for the wobbler and spectrum analyser.

If a hard disc is available as well, if the computer is faster, and if more main memory is available, plus RAMDRIVE and a colour monitor, then naturally everything is even more splendid. Above all, everything can be done much faster!

10.3. Installation

To be able to use the **HFMESS** program, it is more advisable to copy it into a sub-directory of its own on the hard disc.

MD C:\HFMESS

COPY A:*.*C:\HFMESS

10.4. Program Start

In order to start the program, go into the directory on the hard disc and call the program up by its name, **HFMESS**, or start it through a batch file.

After a short loading time, the program briefly introduces itself, and then displays a menu with its functions:

Synthesiser
Wobbler
Milliwatt meter
Spectrum analyser

Calibration
Error list

End

The red bar above the individual menu items can be moved up and down using the cursor key. Press the "Enter" key to go to the selected function.

10.5. Synthesiser

The sub-program ***Synthesiser*** displays two windows on the operator screen. The top window displays the name "Synthesiser", the current frequency and the output level.

The frequency can be varied between 10 MHz and 1400 MHz. The output level lies in the range -10dBm to +10dBm.

The message "UNCAL" may be displayed in the output level field, due to tolerances in the hardware (PLL oscillator, mixer and level regulator). The inter-relationships are discussed in Section 10.9., "Calibration".

The bottom window on the screen indicates the significance of individual keys and their functions.

The frequency can be changed, step by step, by moving the cursor key left or right, and the level can be changed, step by step, by moving the cursor key up or down.

Use the "Return" ("Enter") key to go to an entry window, into which the desired frequency can be entered directly via the keyboard.

This entry procedure is terminated using "Enter".

Use F1 to view the "Help text", which depends on the context. Press "Enter" or "Esc" to leave this text.

Use F10 to leave the "Synthesiser" function and go back to the main menu.

10.6. Wobbler

When the ***Wobbler*** function is selected, the screen is set up in graphics mode. This preparation is directly dependent on the processor output and the VGA card speed.

A large, wide window in the top half of the screen shows the wobble curve, while the bottom left-hand window shows the current values for the mean frequency and the span in MHz. The bottom right-hand window, on the other hand, shows the control options through the keyboard.

The mean frequency can be changed step by step by moving the cursor key left or right (half span) and the span (wobble width) can be changed step by step by moving the cursor key up or down, from ±10 MHz to ±500 MHz.

Use the "Enter" key to go into an entry window where the mean frequency can be set through direct entry. This entry procedure is to be terminated using "Enter".

The program monitors the technical options and prevents the frequency limits from being exceeded.

Use F10 to leave the "Wobbler" function and return to the main menu.

10.7. The Milliwatt Meter

Three windows are displayed in the ***Milliwatt meter*** function. At the top right, you can see the measured output in milliwatts in particularly large characters, which can still be seen easily, even from some distance away. Below this is a horizontal yellow bar, which changes in line with the output for tuning purposes.

At the bottom left, the current readings are shown, such as milliwatts, output in dBm, voltage in Volts, and naturally, the frequency range set.

The bottom right window shows the operating options.

The frequency band can be selected by moving the cursor key up or down. Here

the program takes account of frequency-dependent non-linearities of the diode detector and converts the readings accordingly.

Use F1 to call up the context-dependent help text, and "Enter" or "Esc" to leave it again.

Use F10 to leave the "Milliwatt meter" function and return to the main menu.

10.8. The Spectrum Analyser

When the ***Spectrum Analyser*** function is selected, the screen is set up in graphics mode. This preparation is directly dependent on the processor output and the speed of the VGA card.

A large, wide window in the top half of the screen shows the measured frequency spectrum. The bottom left window shows the current values for the mean frequency and span in MHz.

The bottom right window, on the other hand, shows the control options through the keyboard.

Moving the cursor key to the left or right changes the mean frequency step by step (half span) and moving the cursor key up or down changes the span step by step from ±10 MHz to ±500 MHz (wobble width).

Use the "Enter" key to enter an entry window, where you can enter the mean frequency directly. Press "Enter" to terminate this entry procedure.

You can now use F2 to select the intermediate-frequency band width - band widths of 500kHz and 5MHz are possible.

The program monitors the technical options and prevents the frequency limits from being exceeded.

Use F10 to leave the "Spectrum Analyser" function and return to the main menu.

10.9. Calibration

The ***Calibration*** function runs through the entire available frequency spectrum, step by step. The maximum output power of the frequency synthesiser is measured every 1 MHz, and the level settings in the range from +10dBm to -10dBm are determined as well.

The test reading is graphically represented in the top half of the screen.

Carrying out a successful calibration is a pre-requisite for the functioning of the "Synthesiser" and "Wobbler" applications.

Possible tuning problems - e.g. maximum output level smaller than +10 dBm - are outputted in the form of an error list (cf. Section 10.10. "Error list"). When the calibration is complete, this table is displayed for the user in a window on the lower left-hand side.

The "Calibration" program item is time-intensive! In unfavourable circumstances, e.g. with slow computers or if the parameters have not been set optimally, the complete running time may amount to 10 - 15 minutes.

While the reading is being determined, the function can be interrupted at any time, just by pressing a key. In that event, the calibrated values are not updated (file CALIBRI.BIN) on the hard disc.

10.10. Error list

When the ***Error List*** menu item is called up, it is set up for graphical display. Implausible measurement values are shown in table form as frequencies, theoretical levels and actual values.

If this table takes up more than one screen page, the display can be changed through the cursor keys.

Use F1 to view the context-dependent help text and "Enter" or "Esc" to leave it again.

"Esc" terminates the error list display and returns you to the main menu.

10.11. End

With this selection, the **HFMESS** program is completed, and the screen returns to what it was before the call-up procedure.

After a brief farewell, you return to the DOS operating system level.

10.12. The Configuration File

In the ***HFMESS.CFG*** file, various parameters, essentially conditioned by the hardware, are added to the ***HFMESS.EXE*** program.

The individual values are briefly outlined below:

READINGS = MWTABLE
Conversion table for diode detector

AD-DELAY = 200
Time delay A/D converter (1..1000)

IQ-DELAY = 20
Transmission pulse time delay (1..1000)

PRNPORT = LPT1
Centronics interface (LPT1..3)

FREQUENCY = 1200 Mean frequency target (0..1400)

MENU = HFMESS
Description of option screen

SPAN = 2
Frequency span (1, 2...6)

WOBBLE STEP = 4
Step width for wobble measurement (1..16)

MAXVOLTSA = 2.0
Max. output spectrum of spectrum analyser

MINVOLTSA = 0.4
Min. output voltage (noise)

MAXOUTSYN = 17
Max. output level (dBm) of synthesiser

PRINTERDRIVER = ...
Hard copy function (carried out later)

PRINTERCHECK = ON
Printer test (carried out later)

TEMPDRIVE = C:
Description of RAM disc, if applicable

10.13. The Readings Table

MWTABLE.TXT

The electrical behaviour of the diode detector (Fig.20) is summarised in the MWTABLE.TXT table, including necessary correction factors for frequency and voltage. Any standard text editor allows the correction of this table and thus the capture of the current values for the detector in use.

– *Diode detector characteristic line*

For the diode detector, the output voltage should be measured in relation to the input power. This can be done in a satisfactory way with a digital voltmeter and a test transmitter for, e.g., 144 MHz. A transceiver with adjustable transmission power can be used as well, of course.

The program is designed for a precision (minimum step width) amounting to 1 dB. The voltage values measured are to be entered in the table MWTABLE.TXT in data fields MESSWERTTABELLE [-, 3].

– *Frequency correction*

At high frequencies in particular, the input impedance diverges, in reality, from the desired 50Ω. A correction factor in the data fields FREQQUENZTABELLE [- , 2] balances this out through a computer.

The factor should be measured for the frequency range 28, 50, 144, 432, 1296 and 2320 MHz, with a control power of - for example -1mW (0dBm).

Frequency correction =
Theoretical value at 144 MHz / Reading

– *Correction factor, ΔU*

Small tolerances for the components, or even for the D / A converter ZN 426E-8, result in divergences in the measuring voltage. The ëU factor acts as a computer correction. Its value is app. 0.0099. The reference voltage can be precisely measured at pin 5 / 6 of the D / A converter, using a digital gauge.

$$\Delta U = U_{Ref} / 256$$

10.14. HFMESS.MNU

The HFMESS.MNU file contains the individual items of the main menu, with a description and a screen number (e.g. synthesiser; 110).

The description can be changed, but not the screen number allocated. This datum is coded in the program and is thus always pre-determined.

11. Conclusion

As already stated at the start, the test rig just described represents a welcome and cost-effective gauging aid.

Naturally, with this relatively low expenditure, it is not possible to create a high-end apparatus, and so practical work with the radio-frequency rig demonstrates the limits of this technology sooner or later.

Certainly improvements could be made here, as with any circuit. It is important here that individual hardware changes do not also make a change in the software imperative.

Circuit modifications by users can possibly be published in this magazine.

12. Literature

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